NSRP 0251

TOWER CRANES IN SHIPYARDS

- A STUDY -

Prepared for

U s . DEPARTMENT OF TRANSPORTATION

MARITIME ADMINISTRATION

in conjunction with

AVONDALE SHIPYARDS

NEW ORLEANS, LOUISIANA

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PROGRAM MANAGEMENT

This report is one of many projects managed and cost shared by AVONDALE SHIPYARDS, Incorporated, under the auspices of the National Shipbuilding Program. The program is a cooperative effort between the Maritime Administration's Office of Advanced Ship Development and the U.S. shipbuilding industry.

Executive administration and supervision were provided by Mr E.L. James, Vice President, Production Planning, AVONDALE SHIPYARDS, Incorporated.

Project definition was provided by members of the Society of Naval Architects and Marine Engineers, Panel SP-1, Shipyard Facilities and Environmental Effects, and by Mr R.W. Schaffran, Maritime Administration, Office of Advanced Ship Development.

The special advisory group was made up of the following:

Eugene Aspuru: Avondale Shipyards, Inc.
Richard A. Price: Avondale Shipyards, Inc.
Walter P. Manning: Emscor, Inc.
L.P. Haumschilt: National Steel and Shipbuilding Co.

1. INTRODUCTION

1.1. Purpose

The purpose of this study is to examine the suitability of tower cranes for use in dockyards in the United States. Since the tower crane is not widely familiar in the U.S., although it is the workhorse of Europe and the Far East, sufficient information has been given to allow both the theory and operation of tower cranes to be understood. The cost and cost-effectiveness of tower cranes are examined, and applications for which they are particularly suited are presented in detail.

It is intended that the data and conclusions offered in this study would be of value to any U.S. shipyard during the planning and acquisition of replacement cranes.

1.2. Problem

It is now apparent that the cranes traditionally used in U.S. shipyards do not offer the performance, the flexibility, or the cost-effectiveness of cranes available in Europe and the Far East. Most owners, however, lack sufficient background knowledge to integrate various crane designs into a complete crane package so that the right crane is always available for the job. Without such knowledge, a shipyard can not compete in terms of productivity or of cost-effectiveness. Particularly lacking is an understanding of the role tower cranes can play in the day-to-day running of a yard; this study is accordingly offered to the reader as the first comprehensive discussion of tower cranes in dockyards available in the United States.

1.3. Scope

This study is not exhaustive. It confines itself to shipbuilding and repair operations, leaving aside other maritime applications such as container handling or offshore oil-rig installation. Further, no attempt has been made to discuss tower cranes on a manufacturer-by-manufacturer basis. The study confines itself to general principles as exemplified by particular (typical) cranes. Another self-imposed limitation is that in discussing investment and running costs, exact dollar figures have seldom been given, partly because they are not reliably available, and partly because the currency roller-coaster soon makes such figures worthless. Instead, comparative figures, i.e., cost factors, that can be attached to cranes of

different types have been given. In general, the study has not tried to achieve quasi-scientific completeness; rather, it has highlighted the information a crane owner who was about to make an investment decision might find useful and relevant.

1.4. Acknowledgments

A number of organisations have made important contributions to this study, especially in collecting data about operational cranes -- a time-consuming process -- and in making it available for publication. In particular, the authors would like to thank the following companies and organizations without whose help this study would not have seen the light of day:

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Beratungsstelle fur Stahlverwendung, Dusseldorf, West Germany
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M.A.N. AG, Nurnberg Works, Nurnberg, West Germany
M.M.I., Houston, Texas
National Steel and Shipbuilding Company (NASSCO), San Diego
Newpark Shipbuilding, Houston, Texas
Norshipco, Norfolk, Virginia

Use has also been made of published literature and catalogs of a number of companies, in particular: Peiner, A.G.; Peine, West Germany; Hans Liebherr GmbH Biberach, West Germany; Comedil, Sp.A., Longarone, Italy; Krøll Engineering, Copenhagen, Denmark; Konig Krane, Asbach, West Germany; M.A.N. AG, Nuremberg, West Germany; and M.A.N.-Wolffkran, Heilbronn, West Germany. Other works consulted in the preparation of the study include:

Dickie, Donald. Crane Handbook. Toronto: Construction Safety Association of Ontario, 1975.

Ernst, H. Die Hebezeuge, Bemessungsgrundlage, Bauteile, Antriebe. Braunschweig: Vieweg Verlag, 1973.

Hanchen, R. Winden und Krane, vols 5 and 6. Berlin: Springer, 1932.

Hofmann, F. Krane und Ausrustungen, Materialfluss im Betrieb, 17. Dusseldorf: VDI Verlag, 1973.

Kogan, J. Lifting and Conveying Machine=. Haifa, Israel.

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Michelfelder, C. Transporttechnische Gesichtspunkte bei Hellingen. Dusseldorf: ISTG-Buch, 1909.

Pfeifer, H. Grundlagen der Fordertechnik. Braunschweig: Vieweg Verlag, 1977.

Schmoll, K. Werftkrane. Dusseldorf: Beratungsstelle fur Stahlverwendung, 1968.

Zillich, E. Fordertechnik, vols 1 - 3. Dusseldorf: Werner, 1971.

Tax, H. Tower Cranes. In Proceedings of the First Canadian Construction Crane Safety Conference, Toronto, 1971.

Particular attention must be drawn to Donald Dickie's outstanding Crane Handbook. This is strongly recommended to operators, owners, and users of both mobile and tower cranes.

Walter P. Manning
Dieter Weinreich

Houston/Heilbronn, 1986

TABLE OF CONTENTS

2. MANAGEMENT OVERVIEW

The overview is included to allow the reader to access quickly the argument and conclusions of this study.

PURPOSE OF THE STUDY

The purpose of this study is to familiarize shipyard management with the theory, operation and possible applications of the tower crane.

TOWER CRANES IN HISTORY

The long evolution of the tower crane in dockyards and on construction sites has led to a design that is highly efficient and extremely flexible in operation.

TOWER CIUiNES -- DEFINING CHARACTERISTICS

The shape of the tower crane is not its only defining characteristic. Normally it is a series crane, not a custom built item; further it is a system crane, with a range of interchangeable parts, all of which can be rented for special applications. Two distinctions are important in typing tower cranes: first, tower cranes may slew at the bottom of the tower, or only the jib may slew; then they may have a luffing jib or a horizontal jib with a trolley used for traversing. These two distinctions create four distinct types of crane.

TOWER CRANE THEORY

A tower crane differs from other cranes in the geometry of the balancing forces that keep it stable. Each force (either from the crane, the load, or from external factors such as wind or ice) is exactly balanced by a counterforce with a suitable safety margin added. Unlike many other cranes, tower cranes are constant loadmoment cranes, i.e. , the load raised multiplied by the distance from the tower remains constant.

TOWER CRANE PRACTICE AND APPLICATIONS

In many ways, tower crane operation resembles that of any other crane. A tower crane can work either independently or, when super-heavy lifts are required, alongside a goliath crane. The combination of a tower crane for light lifts and a goliath for heavy lifts is particularly cost-effective. A tower crane offers, in addition, a number of unique advantages. The interchangeability of components (i.e., the fact that it is a system crane) all,ows a wide range of configurations and installations. These can be temporary or permanent, with rentable system-parts available for special jobs. The fact that a tower crane can readily "climb" offers great flexibility, especially in yards that specialize refitting.

TOWER CRANE USE

In day-to-day use, tower cranes operate with smoothness, accuracy and safety. Safety is particularly insured by a range of overload cut-out switches. Operation, especially of horizontal jib cranes, is extremely fast, with measurably superior output per shift. Because a tower crane can be taken down and reassembled in another location and in another configuration within a few hours, efficient operation over a period of years is greatly enhanced.

Environmental factors -- noise, space, and public safety -- present no problems; tower cranes are "city center" cranes, developed for quiet, safe operation in tight corners.

Dockyard equipment is expensive; the tower crane, for its output of work, is relatively the cheapest in terms of initial investment. The add-on potentialities of the system crane, plus the associated rental back-up, enable yards to control initial investment tightly. Training costs and the costs of maintenance are no higher than with other cranes, while running costs are distinctly advantageous. The recent trend to simple design has limited down-time and increased reliability significantly.

A survey of six U.S. dockyards shows their experience with tower cranes to have been universally favorable.

CONCLUSION AND RECOMMENDATION

Tower cranes are not a universal cure-all, but for many applications they offer unmatched productivity and cost-effectiveness. A shipyard developing a crane-mix that guarantees "the right crane for the job" cannot afford to ignore the tower crane.

3. TOWER CRANES IN HISTORY

3.1. Moving Materials in Shipyards

Without efficient means of moving materials, modern industry would be impossible. In shipbuilding today, not only simple materials must be moved, but also gigantic sections of ships, prefabricated elsewhere, must be exactly positioned in the final assembly dock. Enormous slew cranes and goliaths have been developed for such tasks. Within a closed workshop or workbay, extended rail gantries allow overhead traveling cranes to move materials readily and quickly. Does that mean gantry cranes and

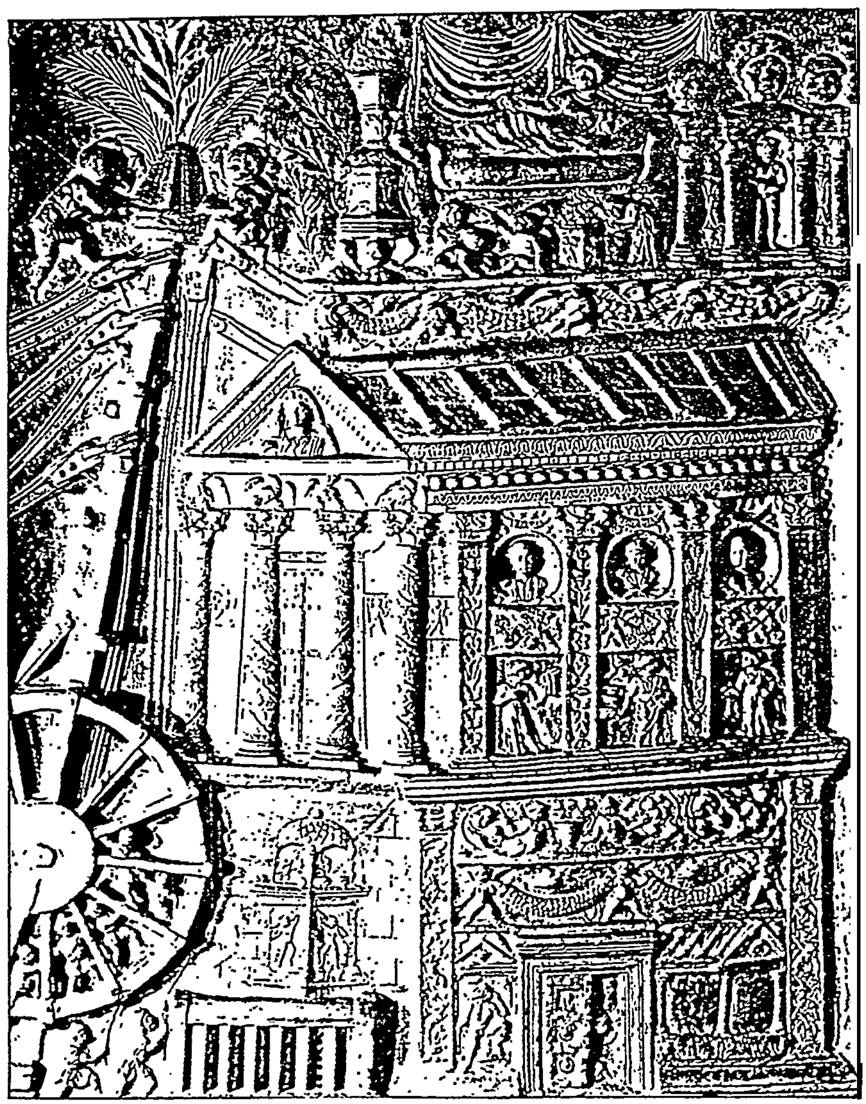


Figure 1

The <u>polyspaston</u> (lst century A.D.) From the tomb of Q. Haterius in Rome

the other dockside giants can fulfill all the needs of the industry? In one sense, the answer is “yes” -- an 800-ton goliath crane can be used to lift a drum of paint-thinner onto the foredeck. But NOT economically. As every shipbuilder knows, misuse of high-capacity cranes -- common as it is -- is simply a waste of time, energy and money.

Historically the problem of moving light loads around a shipyard has been solved by using some kind of tower crane. It is interesting to glance at some of these early tower cranes, since they preview the principles underlying modern tower crane theory.

One of the earliest depictions of crane technology dates back 2000 years to a sculpture on the tomb of Quintus Haterius in Rome. (See Figure 1.) The so-called “polyspaston” is simply a rudimentary tower crane making extensive use of pulleyblocks and powered by a treadmill at ground level.

From Roman times until the middle of the nineteenth century, masts, booms, ropes and pulleys -- coupled with a great deal of ingenuity and experience -- sufficed to build surprisingly big ships. (See Figure 2.)

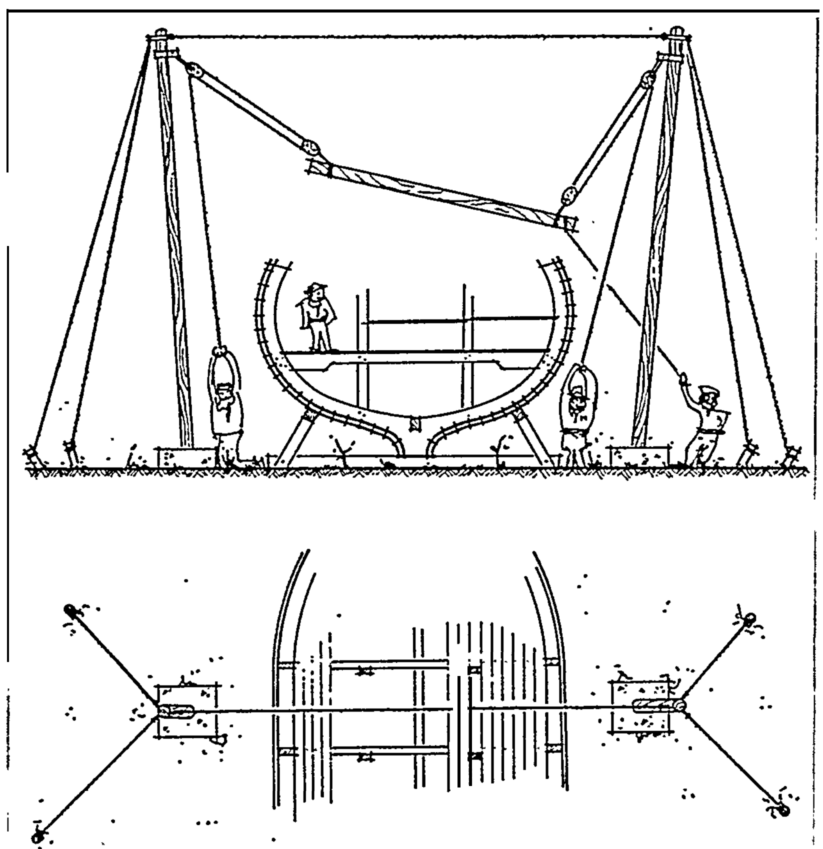


Figure 2

Material handling in European shipyards, 18th-19th centuries. The footstones and ballast-stones are removable. (From a model in the Museum of Hamburg History)

The Elb-Ewer is a good example. This ship was 100 feet long and displaced nearly 200 tons. Prime movers in the dockyards were treadmills and capstans powered by horses or oxen. Reduction gears were made of wood, with pegged teeth and spikes. As late as 1850 a difficult operation such as careening was still carried out by essentially Roman methods -- a wooden pole crane and a two-man treadmill, even in an industrialized 90-ahead port like Hamburg. (See"Figure 3.)

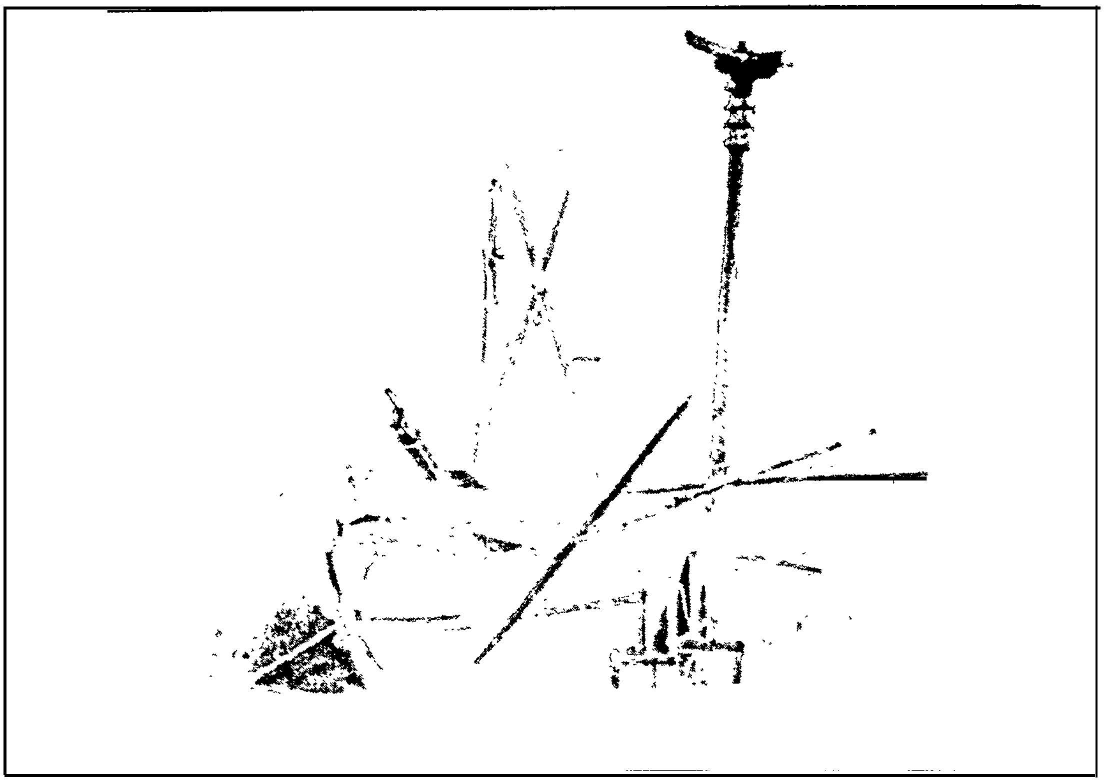
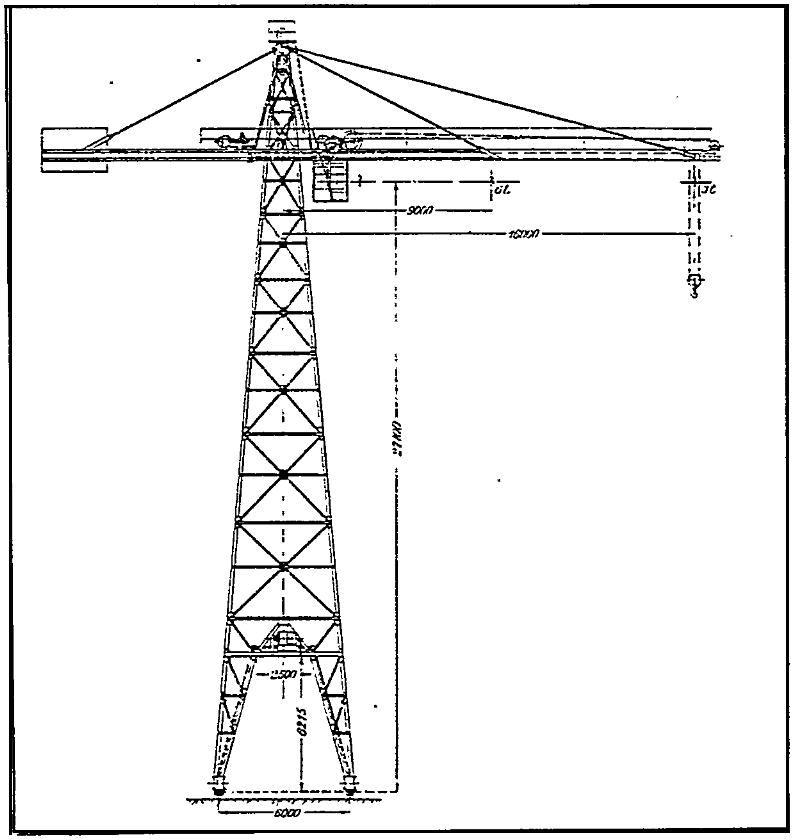


Figure 3: Careening a ship in the Port of Hamburg, 1850. Painting by A.F. Vollmer, (b. 1806)

1.3. The Modern Tower Crane

With the industrial revolution iron became the basic construction material. From 1850 onwards, crane design began to develop, although large iron cranes do not appear until relatively late in the nineteenth century. Their design developed directly from the ancient tradition of crane construction -- they were <u>tower cranes</u>. One of the earliest big iron cranes, a sensation <u>in its dayr</u> was a tracked slew crane nearly 100 feet tall. It was built by Bechem and Keetman for the Vulkan Vegesack yard in Bremen. (See Figure 4 and Figure 5.) Other manufacturers soon got in on the act: Vereinigte Maschinenfabrik Augsburg-Nurnberg, Ludwig Stuckenholz, and most



Specification:

Capacity:	13 300 lbs at 29 ft (6 tons at 9 meters) 6 600 lbs at 52 ft (3 tons at 16 meters)
Height under hook:	89 ft (27.1 meters)
Track gauge:	20 ft (6 meters)
Crane type:	Tracked, top-slewing electric tower crane
Year:	C. 1898 (first reported on 1909)
Manufacturer:	Bechem and Keetman
Yard:	Vulkan Vegesack, Bremen, West Germany

Figure 4: One of the first electric tower cranes built

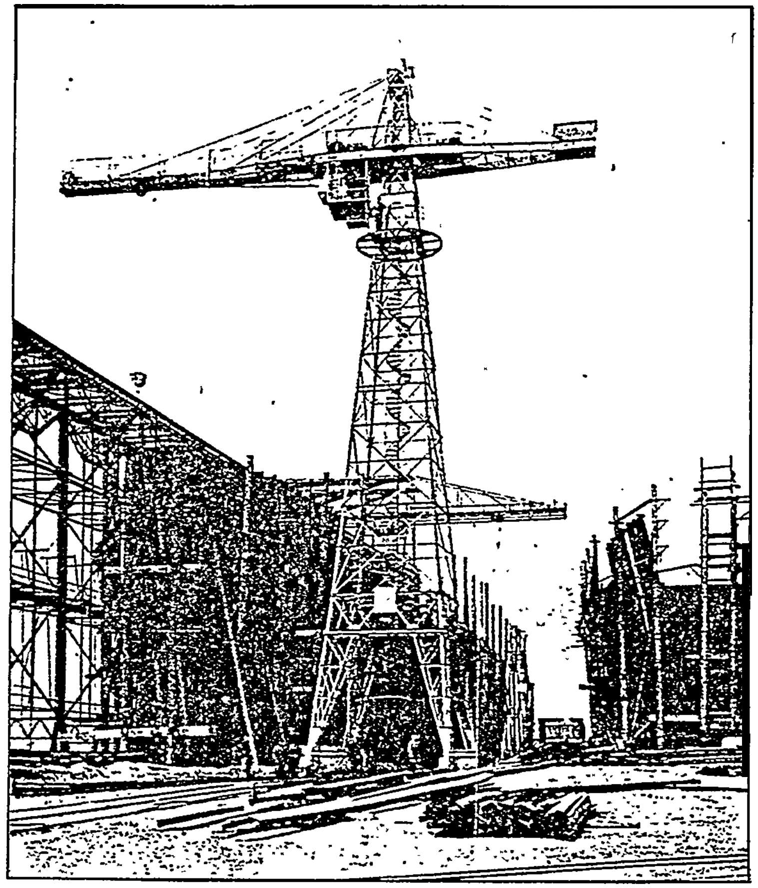
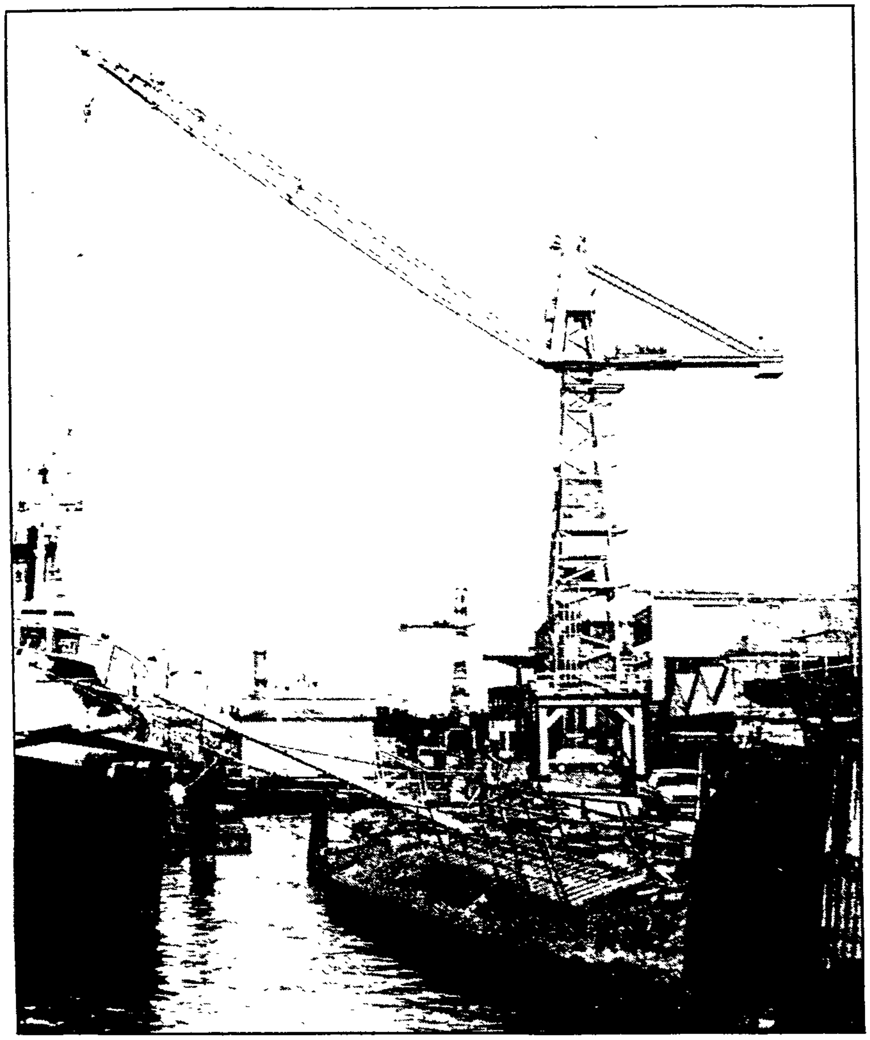


Figure 5: Photograph of the crane described in Figure 4

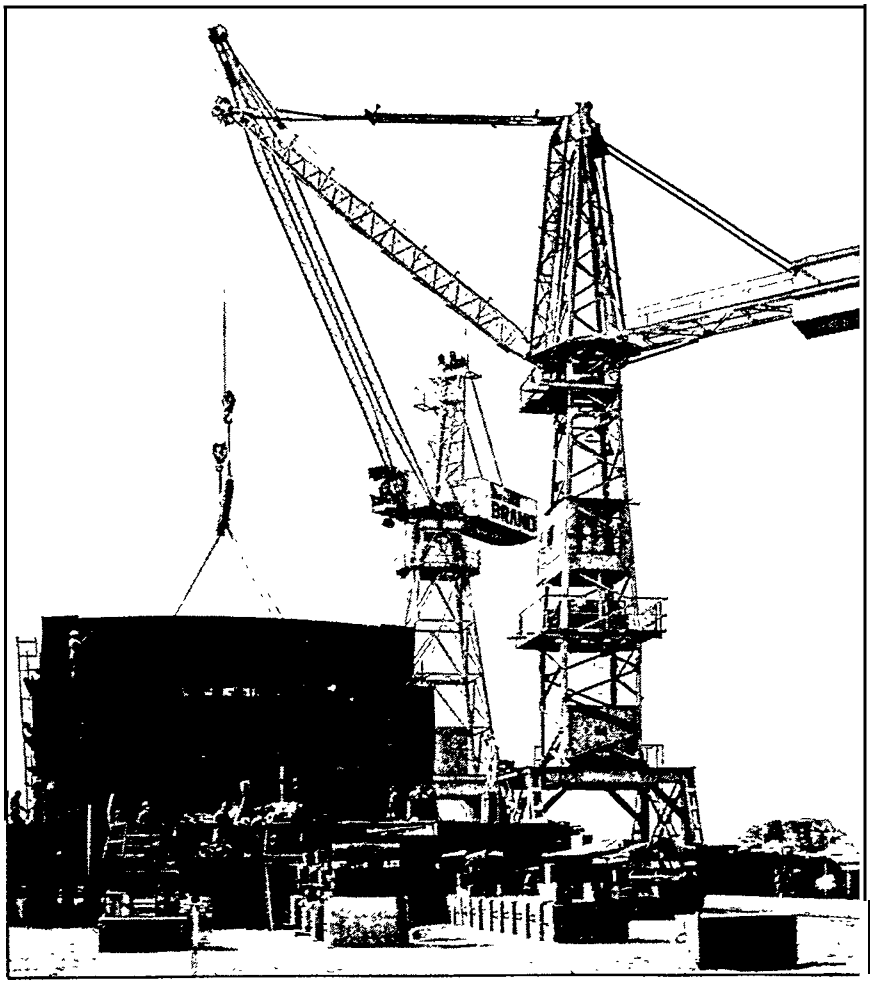
notably Benrather Maschinenfabrik. Most of these cranes were tailor-made for a particular shipyard. It was not until 1908 that Julius Wolff, a Swabian crane manufacturer, introduced the first series tower crane. Customers could now buy a top-slewing, luffing-boom crane “off the shelf.” These cranes were not designed specifically for shipyard use, but many hundreds were installed by shipbuilders. (See Figure 6.) With frequent modifications, this basic design remained in production until the late sixties. The very last Wolff T-crane was installed in the Heinrich Brand yard in Oldenburg as recently as 1968. (See Figure 7.) In 1930, Wolff introduced another kind of tower crane -- the horizontal-boom crane -- for use on building sites. The design proved very popular and was immediately snapped up by shipyards which saw how the economy and efficiency of the design would benefit shipbuilding operations. (See Figure 8.)



Specification:

Capacity:	3 300 lbs at 82 ft (1.5 tons at 25 meters) 8 800 lbs at 33 ft (4 tons at 10 meters)
Height under hook:	162 ft max (49 meters) With additional tower sections
Series portal gauge:	20 ft (6 meters)
Crane type:	Tracked, top-slewing luffing-jib tower crane
Year:	1938
Manufacturer:	Julius Wolff and Co GmbH, Heilbronn, West Germany
Yard:	Schichau-Unterweser AG, Bremerhaven, West Germany

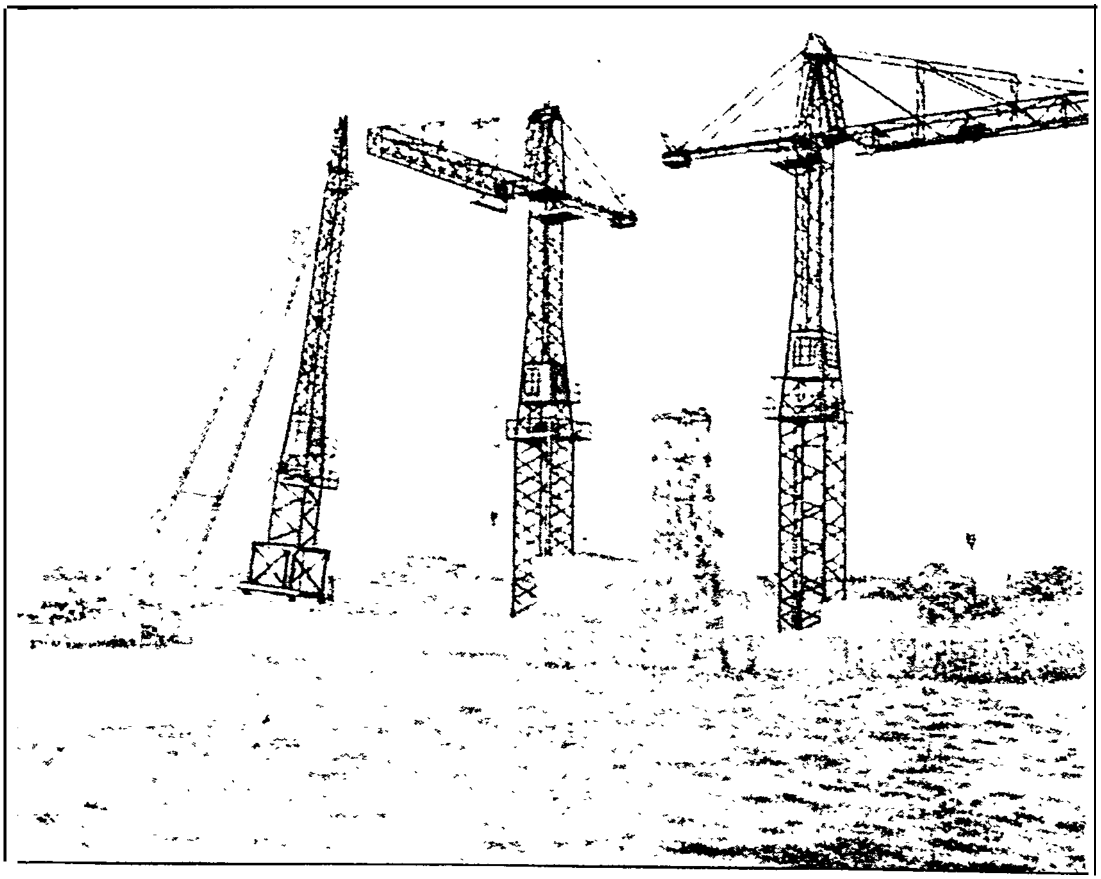
Figure 6: Wolff Type 45 Crane. The first series tower crane. Manufactured 1908-1954



Specification:

	Right Crane	Left Crane
Capacity:	17 600 lbs at 66 ft (8 tons at 20 meters) 26 500 lbs at 49 ft (12 tons at 15 meters)	17 600 lbs at 72 ft (8 tons at 22 meters) 35 300 lbs at 36 ft) (16 tons at 11 meters)
Height under hook:	118 ft (36 meters)	
Portal gauge:	16 ft (5 meters)	
Crane type:	WK 150 EW, on portal	WK 180 EW, on portal
Year:	1956	1968
Manufacturer:	Julius Wolff and Co &!bH, Heilbronn, West Germanv	
Yard:	Heinrich Brand KG, Oldenburg, West Germany	

Figure 7: Top-slewing luffing-jib tower cranes in shipyard operation



Specification

Capacity:	22, 000 I.bs (10 tons) over entire range
Height under hcok:	132 feet (40 meters)
Crane type:	Top-slewing,self-erecting, WK 200 H
Year:	1930's
Manufacturer:	Julius Wblff and Co QnbH, Heilbronn, West Germany
Location:	Working on the belt-bridge in the Baltic Sea, building piers and pillars
Remarks:	The cranes were portable, as can be seen above where a derrick shifts a crane into a new position

Figure 8: Horizontal jib tower crane of the thirties

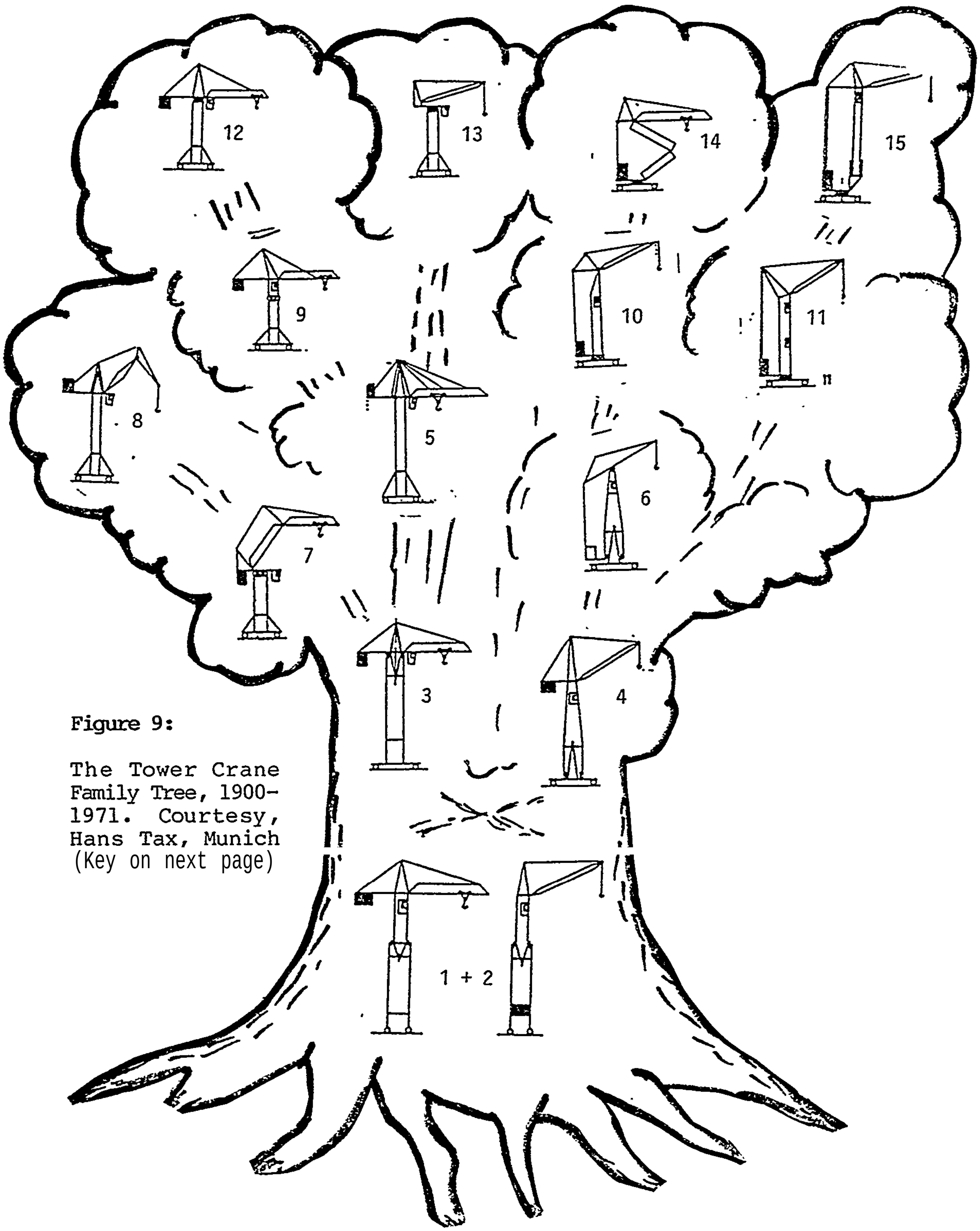


Figure 9:

The Tower Crane Family Tree, 1900-1971. Courtesy, Hans Tax, Munich (Key on next page)

The Tower Crane Family tree, 1900-1971

Cranes 1 and 2	The ancestors	1890's	1. Custom -built, horizontal-jib tower crane 2. Luffing-jib tower crane, custom-built for shipyard duty
Cranes 3 and 4	The first progeny	1900-1940 ' s	3. Tower crane with horizontal jib built in short series nmstly for shipyards 4. Tower crane with luffing jib built in long series for contractors and shipyards
Cranes 7 and 8	The folding-jib branch	1960+	7. German type, 1960 8. Swedish type, 1970
Cranes 5, 9, 12	**Main branch:** Horizontal-jib cranes	1970+	5. With heavily braced jib, 1970 9. Anmre elegant system, 1975 12. Tcday's horizontal-jib crane
Cranes 6, 10, 14	Collapsible-tower branch	1940+	6. Fold-away jib, 1940 10. Fold-away jib and tower, 1955 14. Today's fast-tower cranes: many systems featuring folding or telescoping towers and jibs
Cranes 11 and 15	Big luffing-jib branch	1970+	11. Standard model of 70's 12. Sophisticated telescoping tower, 1975

Modern tower-crane design started out with two notable ancestors: the luffing-boom crane and the horizontal-boom crane. The geometry of the tower-crane has encouraged constant, fruitful experiment with three goals always in mind: speed of handling, economy of energy, and the fullest exploitation of the tower crane's potential for safe, flexible operation. Figure 9 presents the main branches of the tower crane family tree. Few engineering concepts have provoked so much ingenuity and variety as the modern tower crane.

4. TOWER CRANES -- WHAT ARE THEY?

4.1. Tower Cranes and the International Standard Organization

With the almost endless variety of tower cranes in existence, there is sometimes a problem in deciding what is, and what is not, a member of the family. The International Standard Organization (1S0) has a committee addressing exactly this question. The somewhat arcane title of the committee is 1S0 TC 96 SC 7 -- (where TC = Technical Committee and SC = Subcommittee). Sc 7, as it is usually known, has special responsibility for tower cranes; it has developed the following definition:

> A tower crane is a "slewing jib type crane with jib located at the top of a vertical tower . . . . This power-driven appliance shall be equipped a means for raising and lowering suspended loads and for movement of such loads by changing the loadlifting radius, slewing, or traveling of the complete appliance. Certain appliances may comply with only one or several of these movements. The appliance may be installed in a fixed position or equipped with means for travel and/or climbing."

As to the applications of such cranes, at first SC 7 was split. The European members wanted to limit tower cranes to applications on building sites and in storage yards; the U.S. members, on the other hand, wanted a wider range of tasks included -- in particular shipbuilding and other shipyard uses. The whole subcommittee finally swung behind the American view. This means that an 1S0 standard for tower-crane applications in shipyards will be forthcoming shortly.

4.2. Tower Cranes -- Defining Characteristics

In essence, the ISO definition says that a tower crane fulfills the normal functions of a crane but is characterized in particular by mounting a slewing jib atop a tower. While this is, of course, true, in practice tower cranes have developed other standard characteristics, probably because engineers have exploited the advantages of this design to the full. Typically a tower crane has a slender, high tower, which to the layman may look fragile, but which the engineer knows is a triumph of mathematical elegance. The jib (whether horizontal or luffing) is also very long -- again exploiting the "mathematics" of tower-crane design. In nearly all designs, the hook is mounted on a lower block.

A glance at a tower crane in operation shows that it must be getting an enormous amount of lift for the weight of steel built into the crane. This weight advantage has had important consequences. It has meant that many kinds of installation are possible, both temporary and permanent. It is surprisingly easy to assemble a tower crane in one place for a particular job, then to disassemble it and rebuild it elsewhere. This kind of portability makes renting cranes, even quite large ones, a reasonable option.

Light construction weight has also had a profound effect on the manufacture of tower cranes. Because assembly, disassembly and modification are so easily performed tower cranes are characteristically series cranes. This was the manufacturing breakthrough realized by Julius Wolff nearly a century ago. In line with the customer's needs, the manufacturer can readily adapt and modify the basic series design. The cost saving is considerable. Developing from the idea of a series crane, today's tower cranes and also system cranes. This means that additional parts, optional extras and accessories allow flexibility <u>after</u> the initial installation of the crane: boom length, height, hoist speed and so on can all be revamped to meet an ongoing or a one-off requirement. System accessories can even be rented.

A tower crane is thus much more than just a crane on a tower. From the implications of lightweight construction, a whole design philosophy has developed and flourished. Accordingly, when "tower cranes" are mentioned in this study, it not merely their shape that should come to mind, but their movability and the flexibility that comes from series production and system design.

4.3. Tower Crane Types

The classic distinction between tower cranes concerns the jib (or boom). The jib is either fixed and horizontal with the hook moved in and out by means of a trolley, or it is a luffing (derricking) structure familiar since ancient times. A second important distinction concerns the point at which slewing occurs. There are two possibilities: either the tower remains stationary and the jib slews, or the whole tower and the jib slew together. These two distinctions add up to the four basic types of tower crane:

Type 1:	Horizontal jib, top slewing	(Figure 10)
Type 2:	Luffing jib, top slewing	(Figure 12)
Type 3:	Horizontal jib, low-level slewing	(Figure 14)
Type 4:	Luffing jib, low-level slewing	(Figure 16)

Since this typology will be important in much of what follows, it is worth glancing at the four illustrations on the next pages to establish the types and the terminology clearly in mind.

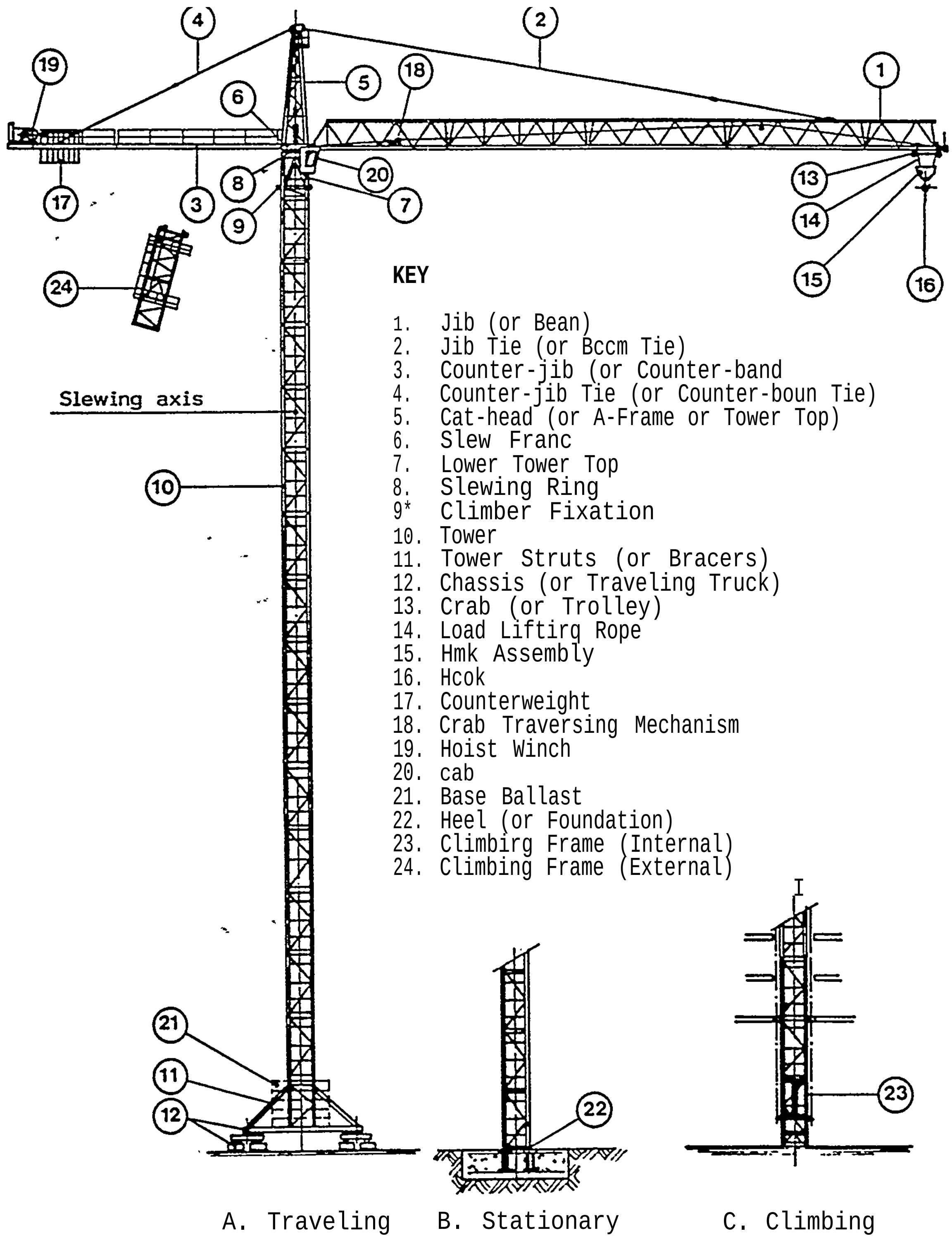


Figure 10: TYPE 1 TOWER CRANE -- With top-slewing horizontal jib

TYPE 1 TOWER CRANE : Technical Specifications

Manufacturer and Type

MAN-Wolffkran, Type WK 325 SL. Top-slewing, horizontal jib

Basic Specification

Maximum Load: 26 500 lbs
Maximum Reach: 230 ft
Maximum Free Standing Height under Hook : 211 ft

Geared Capacities *

Gear Step 1: 0 - 4 400 lbs
Gear Step 2: 0 - 8 800 lbs
Gear Step 3: 0 - 13 200 lbs

Speeds

Hoist Speed * : 0 - 200 ft/min to O - 576 ft/min with 2 falls
Trolley Speeds: 79 or 156 or 315 ft/min
Slewing Speed : 0.7 rpm

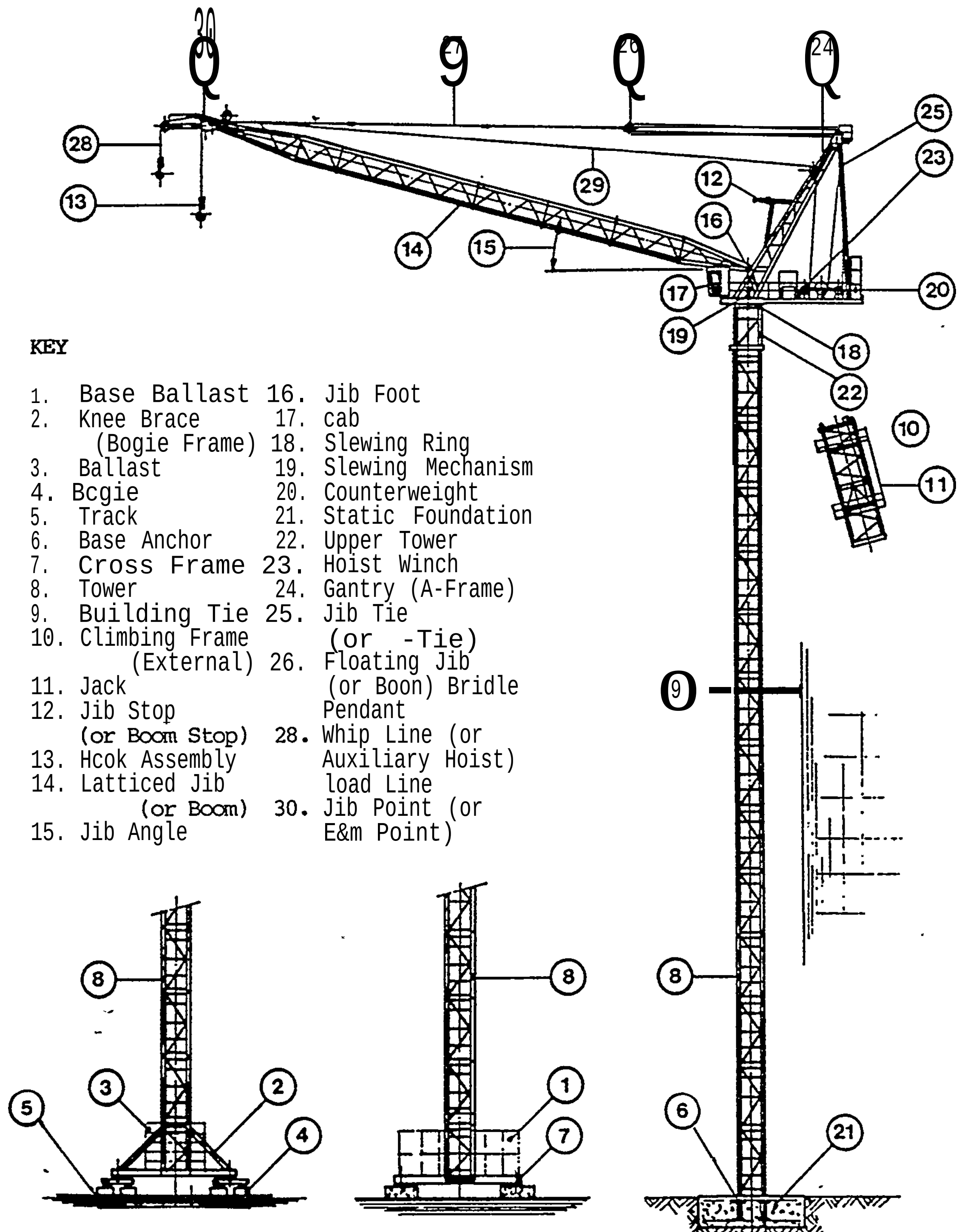
Tower Section Dimensions

Length : 14 ft 9 in
Section: 6 ft 6 in square

(* Note: Semi-automatic switch from 2 falls to 4 falls doubles capacities and halves speeds)

	Jib length, ft (maximum hook reach)								
Liftradius,ft	98	115	131	148	164	180	197	213	230
0 to 60	26,500	26,500	26,500	26,500	26,500	26,500	26,500	26,500	26,500
0 to 72	26,500	26,500	26,500	26,500	26,500	26,500	26,500	25,600	24,200
0 to 75	26,500	26,500	26,500	26,500	26,500	26,500	25,200	24,400	23,100
0 to 78	26,500	26,500	26,500	26,500	26,500	25,300	24,000	23,300	22,000
0 to 81	26,500	26,500	26,500	26,500	25,300	24,200	23,000	[illegible]	21,000
0 to 84	26,500	26,500	25,700	25,400	24,300	23,200	22,000	21,300	20,100
98	23,200	22,300	22,000	21,700	20,700	19,800	18,700	18,100	17,100
115		18,800	18,500	18,200	17,400	16,600	15,700	15,200	14,300
131			15,900	15,700	14,900	14,200	13,400	13,000	12,200
148				13,700	[illegible]	[illegible]	11,700	11,300	10,600
164					11,500	10,900	10,300	9,900	9,300
[illegible]						9,700	9,100	8,800	8,200
197							8,200	7,800	7,300
213								7,100	6,600
230									6,000

Figure 11: Maximum Lift Capacity of Type 1 Crane (in lbs)



KEY

1. Base Ballast
2. Knee Brace (Bogie Frame)
3. Ballast
4. Bcgie
5. Track
6. Base Anchor
7. Cross Frame
8. Tower
9. Building Tie
10. Climbing Frame (External)
11. Jack
12. Jib Stop (or Boom Stop)
13. Hcok Assembly
14. Latticed Jib (or Boom)
15. Jib Angle
16. Jib Foot
17. cab
18. Slewing Ring
19. Slewing Mechanism
20. Counterweight
21. Static Foundation
22. Upper Tower
23. Hoist Winch
24. Gantry (A-Frame)
25. Jib Tie (or -Tie)
26. Floating Jib (or Boon) Bridle Pendant
28. Whip Line (or Auxiliary Hoist) load Line
30. Jib Point (or E&m Point)

Figure 12: TYPE 2 TOWER CRANE -- With top-slewing luffing jib

TYPE 2 TOWER CRANE : Technical Specifications

Manufacturer and Type

MAN-Wolffkran, Type WK 320 B. Top-slewing, luffing jib

Basic Specification

Maximum Load:	61 600 lbs
Maximum Reach:	164 ft
Maximum Free Standing Height under Hook:	220 ft (to jib pivot)

Geared Capacities

Gear Step 1:		o - 11 000 lbs
	or	o - 31 000 lbs
Gear Step 2:		o - 22 000 lbs
	or	o - 40 000 lbs
	or	0 - 61 600 lbs

Speeds

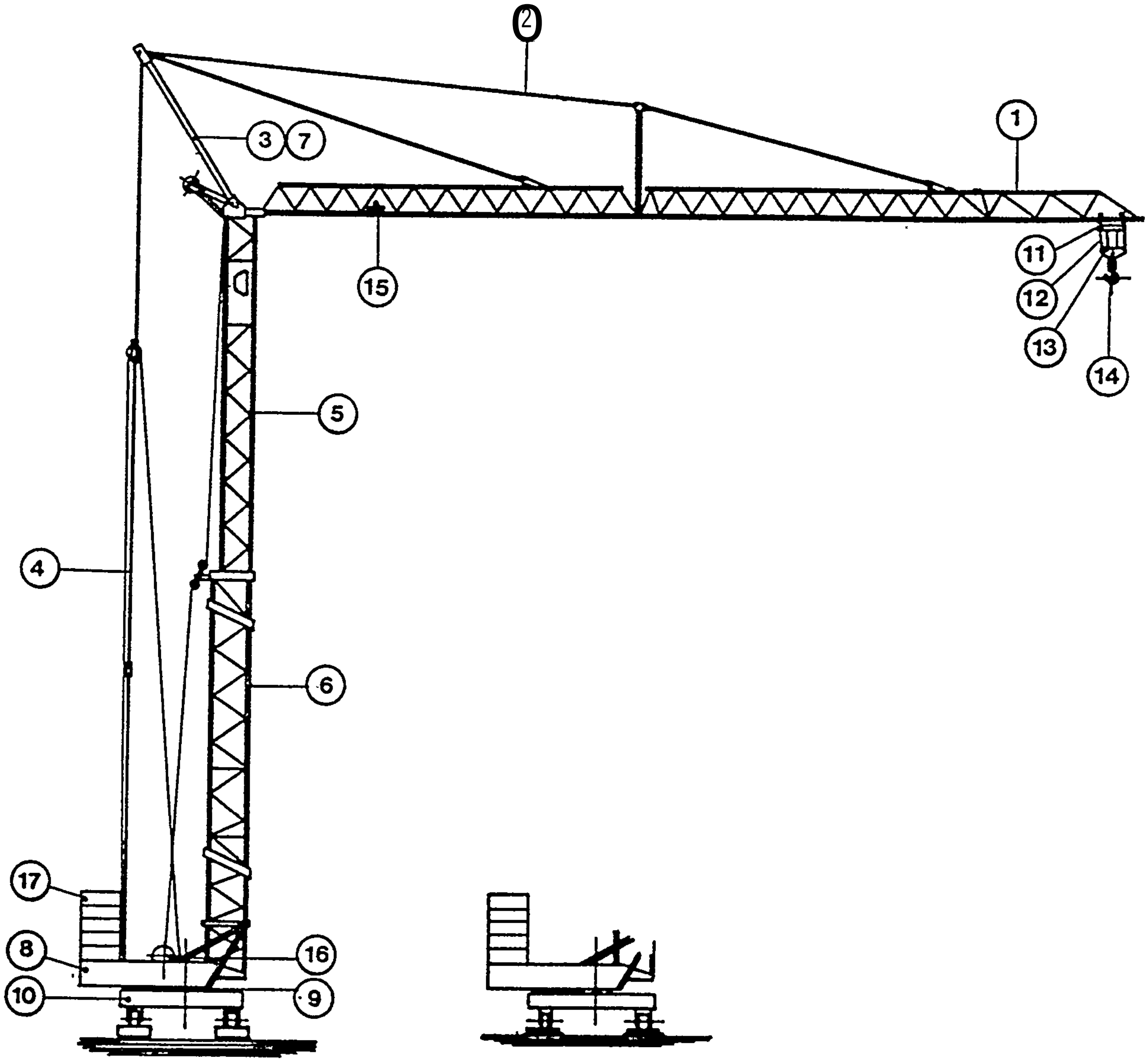
Hoist Speed	: o - 200 ft/min to O - 435 ft/min (stepless)
Luffing Speed	: 41 ft/min
Slewing Speed	: o - 1.0 rpm

Tower SectiOIl Dimensions

Length : 14 ft 9 in
Section: 6 ft 6 in square or 8 ft 2 in square

	Jib lergth				
Lift radius	98	115	131	148	164
0 to 50	62.000	62.000	62.000	62.000	62.000
0t060	57.800	55.6oa	53.600		49.100
0 to 72	45.500	43.500	41.700		37.700
0 to 75	43.150	41.1W	39.400		35.500
O to 78	41.000	38.900	37.200		33.500
Oto84	38.900	36.900	35.300		31.500
98	31.000	28.900	27.500	- unkr wn -	24.000
115		23.150	+21.800		18.600
131			17.6043		14.600
148					11.500
164					9.000

Figure 13: Maximum Lift Capacity of Type 2 Crane (in lbs)



A. Traveling

B. Stationary

KEY

1. Jib (orkan)
2. Jib Tie (or Bean Tie)
3. Jib Support Truss
4. Counterweight Pendant
5. Telescopic Tower
6. Low Level Tower
7. Counter-Jib (or Counter-Ecxxn)
8. Slewing Chassis
9. Slewing Ring
10. Base Chassis
11. Trolley (or Crab)
12. tiad and Lifting Rope
13. Hcok Assembly
14. Hook
15. Trolley (or Crab) Traversing Mechanism
16. Hoist Winch
17. Counterweight

Figure 14: TYPE 3 TOWER CRANE --"Fast Tower" with low-level slewing and horizontal jib

TYPE 3 TOWER CRANE : Technical Specifications

Manufacturer and Type

Koenig, Type K 65. Low-slewing, horizontal jib, fast-tower

Basic Specification

Maximum Load:	13 300 lbs
Maximum Reach:	147 ft
Maximum Free Standing Height under Hook:	106 ft

Lifting Capacities

With 2-part Line: 2 900 - 6 6001bs
With 4-part Line: 2 900 - 13 300 lbs

Speeds

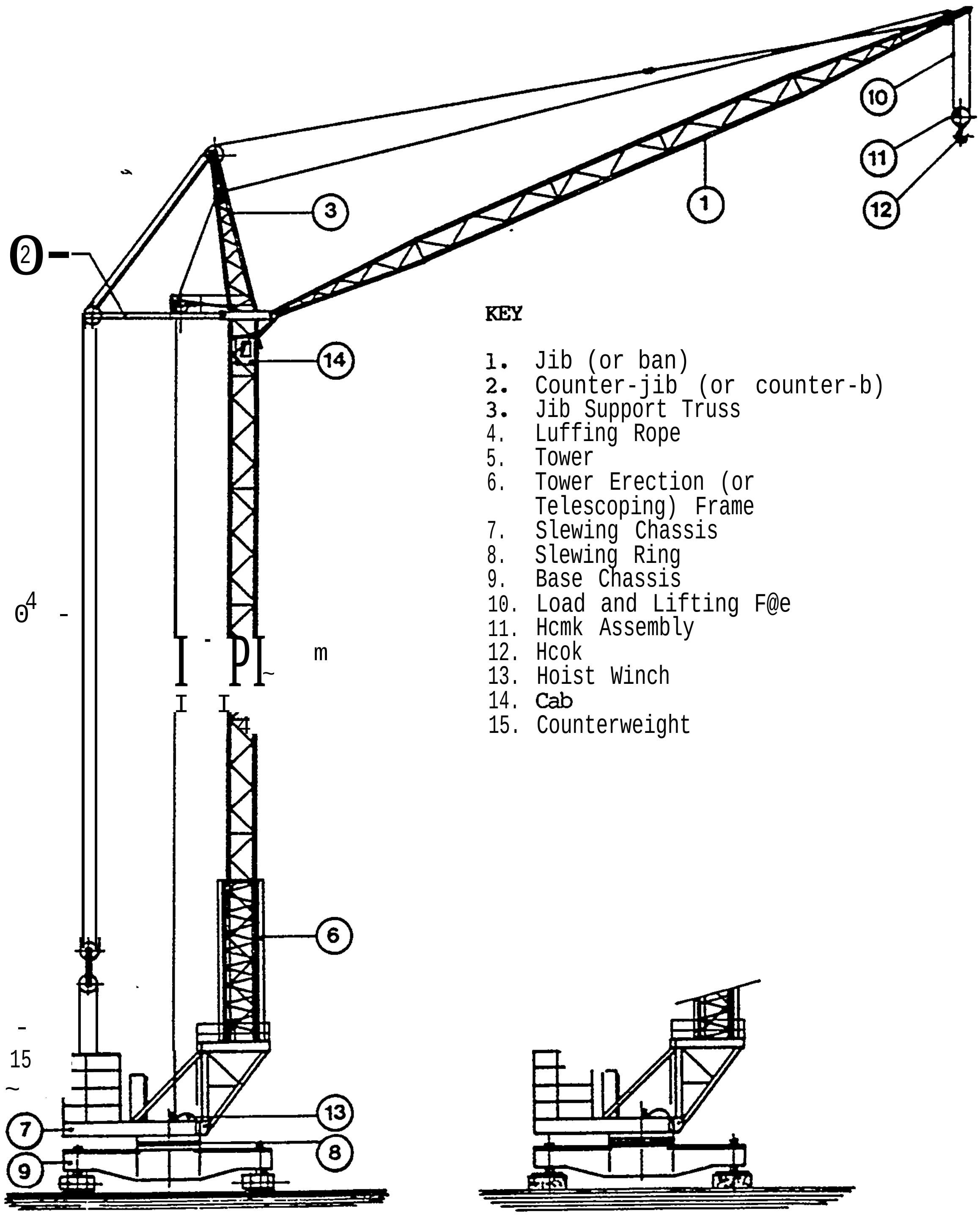
Hoist Speed : With 2-part Line = 30 ft/min - 215 ft/min
With 4-part Line = 15 ft/min - 107.5 ft/min
Traversing Speed : 70 ft\min - 140 ft/min
Slewing Speed : 0 - 1.0 rpm

Tower Dimensions

Section: 4 ft square.

		boom length 147 ft
lift radius		
2 parts	O-76	6.600 lbs
	O - 9 O	5.300 lbs
	o - 110	4.000 lbs
	o - 130	3.200 lbs
	o - 147	2.900 lbs
4 parts	o - 46	13.300 lbs
	o - 60	9.700 ibs
	o - 80	6.200 lbs
	o - 110	4.000 Ibs
	o - 130	3.200 Ibs
	o - 147	2.900 lbs

Figure 15: Maximum Lift Capacity of Type 3 Crane (in lbs)



KEY

1. Jib (or ban)
2. Counter-jib (or counter-b)
3. Jib Support Truss
4. Luffing Rope
5. Tower
6. Tower Erection (or Telescoping) Frame
7. Slewing Chassis
8. Slewing Ring
9. Base Chassis
10. Load and Lifting F@e
11. Hcmk Assembly
12. Hcok
13. Hoist Winch
14. Cab
15. Counterweight

A. Traveling B. Stationary

.Figure 16: TYPE 4 TOWER CRANE -- With low-slewing luffing jib

TYPE 4 TOWER CRANE : Technical Specifications

Manufacturer and Type

Peiner, Type T 125. Low-slewing, luffing jib

Basic Specification

Maximum Load: 13 800 lbs (at 167 ft)
Maximum Reach: 167 ft
Maximum Free Standing Height under Hook: 190 ft (to jib pivot)

Lifting Capacities

This crane has a range of jib lengths with 2-fall, 3-fall and 4-fall options. (See Chart below.) With standard (167 ft) jib:

Innermost radius (69 ft): 13 880 lbs
Outermost radius (167 ft): 5 500 lbs

Speeds

Hoist Speed : 295 ft/min - 82 ft/min (via 3 gear steps)
Luffing Speed : Full range (69 ft - 167 ft) in 63 sees
Slewing Speed : 0.8 rpm

Tower Section Dimensions

Length: 19.8 ft
Section: 6.75 ft square

at radius	with max. boom radius xen L1	L3	L5
	90 ft	129 ft	167 ft
46	35.270		
49	32.850		
56	30.090	20.950	
63	27.340	19.840	
69	24.800	18.850	13.880
76	22.200	17.750	13.230
90	16.530	15.430	11.950
110		12.350	10.360
129		9.370	8.700
147			7.050
167			5.500

Notes :

[11 L2, L4 and L6 are further jib choices not shown here.

[21 Ll operates with 4 falls, L3 with 3 falls and L5 with 2 falls only.

Figure 17: Maximum Lift Capacity of Type 4 Crane (in lbs)

5. WHY IT WORKS -- TOWER CRANE THEORY

5.1. Tower Crane Standards

National engineering standards for tower cranes have been been developed in most leading industrial countries. In the first instance, these standards establish what construction and performance requirements tower cranes must meet. All aspects of construction are closely prescribed: engineering (especially welding); mechanical and hydraulic transmission systems; prime movers -- everything must reach state-of-the-art standards. performance standards are just as strict, especially those dealing with the effect of climate on the working crane. Ice, extreme heat or cold, lightning, gale-force winds -- a tower crane has to be “unbeatable” before it can go into production. And not only are standards set: they are rigidly enforced by teams of independent inspectors conducting in-factory tests. European design uses a “top-down” philosophy: standards are set so that performance is virtually guaranteed. Normally this means that the product is rather better than it needs to be in practice. A bottom-up, “let’s do it this way and see if anyone sues us” attitude is not even theoretically possible. The main European standards that apply to tower cranes are:

DIN 15018, H2 - B3	(West Germany)
BS 2573, Group 2	(Great Britain)
AFNOR	(France)
FEM - A/2/3	(Uniform European Code)

When ISO-TC 96-SC 7 is finallv ready, there will be an internationally recognized standard for tower cranes. It will not, however, be significantly different from the standards already prevailing in the industry.

Without going into detail on these standards, essentially they establish the frame of reference for a tower crane:

a. Tower cranes must be able to achieve fast and repeated multilifts over a long life-time.

b. Light-weight construction should minimize the acting and reacting forces in play between the tower crane and its supporting structure, be it temporary or permanent.

c. Since easy dismantling and reassembly are prime features, these operations must be speedy and safe. The crane after many reassemblies must be as safe as it was in its first incarnation.

d. Because movable cranes will be assembled on many different sites and on many different supporting structures, they must guarantee equal safety whatever the mode or site of installation.

Any experienced engineer will immediately see a potential problem here -- misuse or downright abuse by the user. What happens if the crane is incorrectly assembled? If it installed on an erroneously calculated foundation? If it is poorly maintained or repaired? If it is overstressed, with metal fatigue as a result? The answer is simple: the same thing that happens with any other piece of machinery -- trouble. Tower crane manufacturers, and the agencies that set industry standards, have always worked to minimize such trouble, though no engineer can ever hope to outlaw such problems altogether. The approach has three tracks.

Track 1: Mechanical Devices Every tower crane contains a E=ttery of safety equipment: limit switches, overload cut-outs, back-up brakes and so on. If these are kept in normal working order, and if all the signals are heeded, even the threat of trouble is rare.

Track 2: Consulting The distributor or the manufacturer of a tower crane is always ready to provide consulting services if there are any doubts about the installation of a tower crane. Because of its high movability, the tower crane has never been a “sell-it-and-forget-it” product. From the earliest days, manufacturers have been keen to help customers, and of course to polish their own expertise, by directly confronting the day-to-day problems of crane operation.

Track 3: Training Accidents occur with tower cranes -- just as they occur with everything from can openers to jumbo jets. But, in general, tower-crane accidents are not traced back to mechanical failure: human error is almost invariably to blame. Even the (very rare) cases of metal fatigue are the result of prolonged overloading or of failure to retire a crane that has completed its useful life. Manufacturers feel that by providing site engineers with the information they need, by stressing the need for operator training, and by posting clear and sufficient warnings both in the manuals and on the machines, they eliminate all but the crassest kinds of “human error.” But ultimately, nothing can release the owner and operator from their “duty of care” and nothing can guard against the effects of “gross negligence.” Tower cranes are built to the safest possible standards; safe operation must lie in the hands of the user.

5.2. Tower Cranes -- A System of Balancing Forces

The word “crane” as applied to a machine derives from the other “crane” -- the tall, gawky bird that wades in shallow water looking for frogs, and that seems to be equally happy standing

on one leg or on two. Some birds of this type even go to sleep standing on one leg. Odd as it may seem to human beings, provided the bird is correctly balanced, its sleeping position is perfectly stable. Much the same is true of a tower crane.

A tower crane rests on a foundation. At the point of contact, it is subject to four basic forces: <1> vertical forces and <2> horizontal forces, <3> forces that result from slewing, and <4> forces that are exerted by the load and that work to "overturn" the crane. Figure 18 shows these forces diagrammatically.

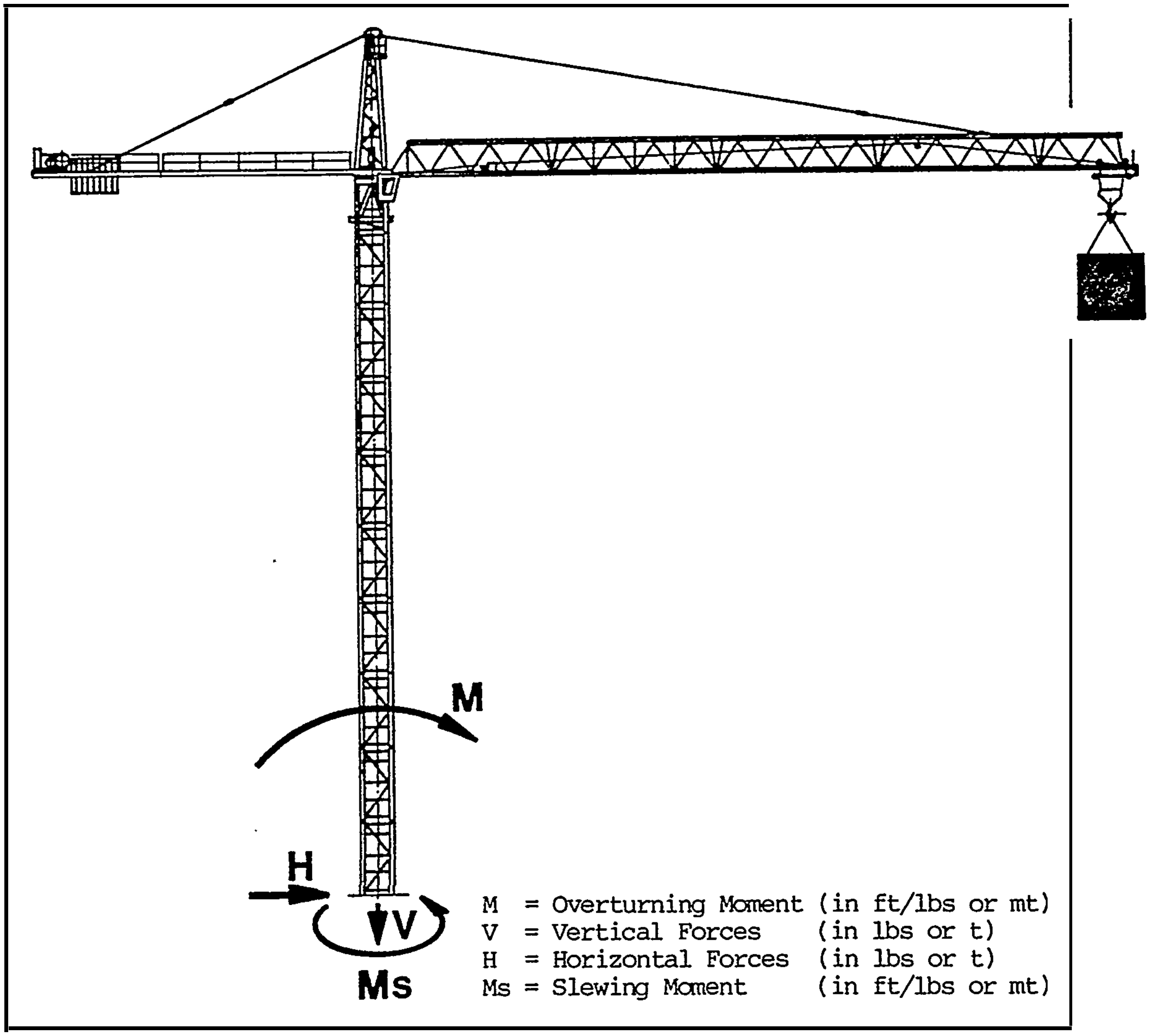


Figure 18: Forces exerted by a tower crane on its foundation

For the crane to be stable in operation, each of these forces must be balanced by an equal (or in practice far greater)

reactive force. In ensuring this balance, there are no rules of thumb. Precise calculations must be made. For any given type of crane, these calculations balance, on one hand, the exact tower configuration, the exact length of the jib, plus the exact capacity of the crane? with, on the other hand, soil conditions and bearing capacity, railwidth and loadbearing capacity, as well as the bearing force and weld-strength of the steel infrastructure in use. Further essential information is the maximum wind force expected during operations and during "out of service" (rest) periods. Two other items must also be considered: <1> possible tilting of the crane during erection, and <2> the freedom of the crane free to "windvane" at all times. Given the necessary tables, these calculations are not difficult to make; nevertheless, the crane manufacturer or distributor should always be consulted in case of doubt.

5.2.1. Infrastructures -- the Kev to Balanced Forces

As examples of possible infrastructures, three of many possible designs are given below in diagrammatic form. (See Figures 19-21.) In each case the infrastructure is calculated to compensate (with a suitable safety margin) for each of the forces brought to bear upon it. The result may look like an exercise in downsizing, but it is not so -- a sheep does not stand in an inherently more stable pose than a whooping cranel nor is a four-wheel car inherently more stable than a two-wheeled motorbike. The infrastructure does the job it has to do.

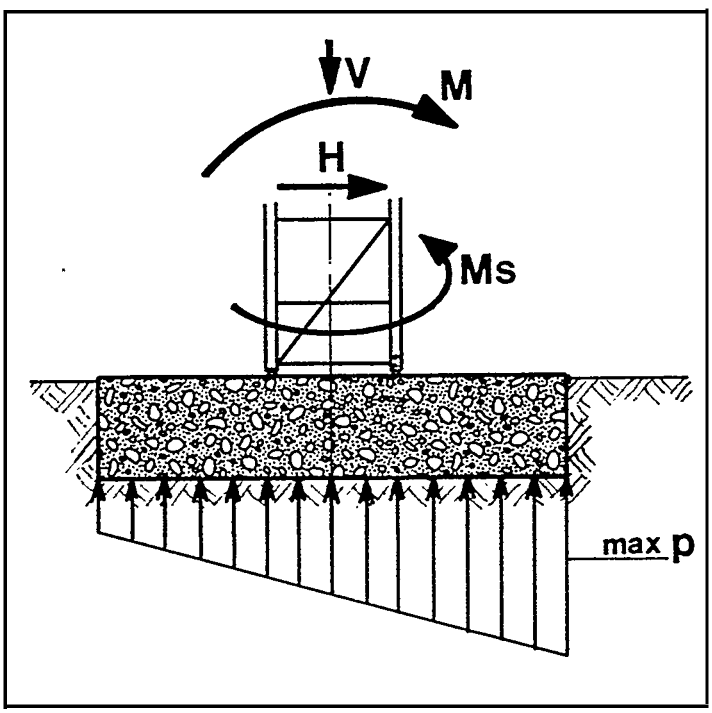


Figure 19:

Pad-type Foundation

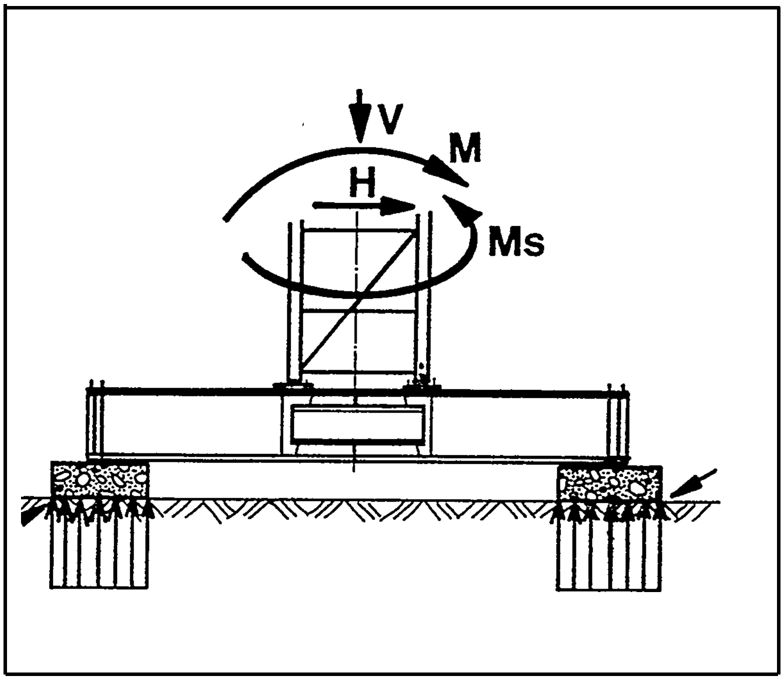


Figure 20:

Cross Frame Foundation

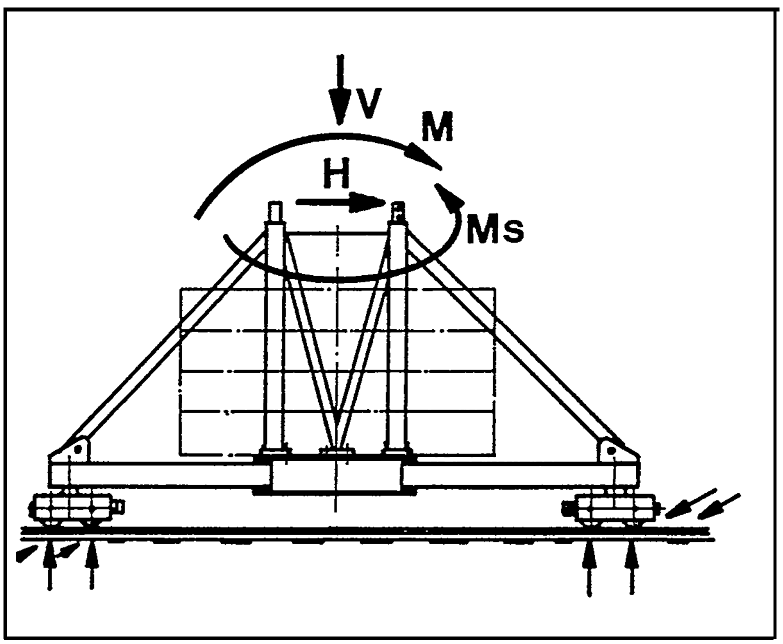


Figure 21:

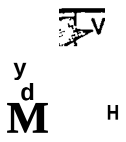
Rail-traveling Undercarriage

As an examDle of the calculations for a Particular crane. the table used-to assess the so-called "Foun-dationloads" f-or a Wolffkran WK 184 SL is given as Figure 22. Following that, Figure 23 shows how the figures for centerballast and cornerloads are derived for the same crane.

XIV 8684

Wolffkran WK 184 SL

Foundationloads



for cranes free standing without climbers on concrete foundationValues given are for least favorable jib length. Other length of jib may result into lower foundation loads.

Always acting loads are:
Vertical forces of loadcase 2 and a moment of 571 ft. kips

free standing height under hook (ft.)	Crane in service (for loadcasel of DIN 1054) torquemoment:148 ft. kipa			Crane out of sem-ce (for loadcaae 2 of DIN 1054) torquemoment: O ft. kips		
	M (ft. kipS)	H (kipS)	V (kips)	M (ft. kipS)	H (kipS)	V (kips)
49.2	1395	13	108	11 87*	9	69
63.5	1561	13	112	1244**	9	72
78.7	1726	13	116	1304**	9	75
93.5	1893	14	121	1368W	9	78
108.3	2064	14	126	1438*	10	82
123.0	2233	14	130	1511-	10	87
137.8	2405	15	134	1669	20	115
152.6	2581	15	140	1971	21	120
167.3	2761	15	147	2294	23	127
182.0	2946	16	154	2636	24	133
196.9	3192	16	163	2966	25	141
211.6	3326	16	172	3364	26	149
“ 22&4	3522	17	181	3716	27	157
241.1	3721	17	190	4144	28	165

*Moments during crane erection

M = Moment
H = Horizontal force
V - Vertical load

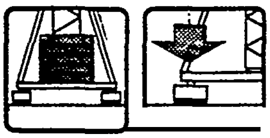
M·A·N WOLFFKRAN GMBH HEILBRONN
Austraße 72 · D-7100 Heilbronn · Telefon (07131) 136-0 · Telex 0728877

18.8.82

Figure 22: Example of a Foundationload Table

XIV12396

WoHkran MK 184 SL



Centerballast and Cornerloads

for stationary cranes without climber on crossframe element

Horizontal forces H and torquemoments to be taken from table “Foundation loads”

KRE 260.2

Height under hook (ft)	98.5 ft-jib				131 ft-jib				148Wib			
	Comerdistance (n)		Cornerdistance (h)		Comerdistance (ft)		Comerdistance m		Comerdistance (ft)		Comerdistance m)	
	16ft 5in	19 ft8in	16 ft5in	19 ft8in	16 ft5in	19 ft8in	16ft 5in	19ft 8in	16ft 5in	19 ft8in	16 ft5in	19 ft8in
	C4nterbakt M		mar- Comerload Mix)		Centerbahst ilb)		ma% Comerlcad (kid		Csrrterballssl (Jb}		max. Comerlcad Ms)	
49.2	132,000	88,000	104	92	110,000	66,000	103	90	110,000	66,000	104	92
63.5	132,000	88,000	107	95	110,000	66,000	106	93	110,000	66,000	108	96
78.7	132,000	88,000	111	99	110,000	66,000	109	97	110,000	66,000	111	99
93.5	132,000	88,000	114	102	110,000	66,000	113	100	110,000	66,000	115	103
108.3	132,000	88,000	118	106	110,000	66,000	117	105	110,000	66,000	119	107
123.0	132,000	88,000	122	110	110,000	66,000	121	109	110,000	66,000	124	112
137.8	132,000	110,000	126	120	132,000	88,000	131	119	132,000	88,000	134	121
152.6	176,000	110,000	142	124	154,000	110,000	141	129	154,000	110,000	147	136
167.3-’	198,000	154,000	155	142	198,000	132,000	167	149	198,000	132,000	174	156
182.0	176,000			163	154,000			171	154,000			178
196.0	Tiix6iiol			185	198,000			200	176,000			202
211.6	220,000			208	220,000			224	220,000			234

Height under hook (ft)	164 ft-jib				ft-jib				ft-jib			
	Comerdistance (ft)		Cornerdistance (N		Comerdistance (ft)		Comerdistance (ft)		Comerdistance (n)		Comerdistance (ft)	
	16 ft5in	19 ft8in	16ft 5in	19ft 8in	16ft 5in	19 ft8in	16t15in	19 ft8in	16 ft5in	19 ft8in	16ft 5in	19 ft8in
	Centerbsllsst (lb)		ma% Camerload (tips)		Cerrterbahst (lb)		msx. Corrrerload (l@)		Centutrallsst (lb)		ma% (%merload (k@)	
49.2	110,000	66,000	106	94								
63.5	110,000	66,000	109	97								
78.7	110,000	W5,000	113	101								
93.5	110,000	65,000	117	105								
108.3	110.000	66,000	121	109								
123.0	110,000	66,000	126	114								
137.8	132,000	88,000	136	123								
152.6	154,000	110,000	154	142								
167.3	198,000	132,000	181	163								
182.0		154,000		185								
196.0		176,000		209								
211.6		220,000		239								

Figure 23: Example of a Centerballast and Cornerload Table

5.2.2. Windforce

Beaufort 8 is the normal upper limit of cargo handling with a tower crane. More important, of course, is the upper limit with the crane inoperative. In fact, there is no upper limit. The crane design can be adapted to ~ local windspeed conditions. The crane manufacturer or distributor will supply full details.

Beaufort and wind speed	m/s	
4	7,9	
5	10,7	
6	13,6	
7	17,1	
8	20,7	in operation
9	24,4	
10	28,4	
11	32,6	
12	36,9	
13	41,4	out of operation
W		
15	50,9	
16	56,0	
17		

Wind speeds			
mls	kmlh	kn	miles/h
10	36	20	22.4
11,2	40	22,4	25
12.5	45		28
14	50	$:	31.5
16	56	31,5	35.5
18	63	35.5	40
20	71	40	45
22,4	80	45	5 7
25	90	50	56
28	100	56	63
32	112	63	71
35,5	**125**	**71**	**80**
40	**140**	**80**	**90**
45	160	90	100
50	180	100	112
56	[illegible]	112	125
63	224	125	140
71	250	140	160
80	280	160	180
90	315	180	200
100	**355**	**200**	**224**

Figure 24:

Wind Data Table

J

5.3. Tower Cranes and the Theory of Load Moment

Tower cranes are almost invariably "load moment" cranes. This simply means that at their extreme radius, their capacity is less than it is closer to the tower. Loadmoment is calculated as a constant:

$$\text{Load} \times \text{Radius} = \text{Constant (Loadmoment)}$$

In practice, the geometry of the crane creates two ranges: the heavy load range and the reduced load range. Within the heavy load range, the capacity of the crane is taken as being constant. When the rating of a loadmoment crane is stated, this is its loadmoment at the outermost radius of the heavy range, the point known as the r_{HV}. Figure 25 shows these ranges for a horizontal-jib and a luffing-jib crane. Naturally, in operation both loadmoment and maximum load are automatically controlled by

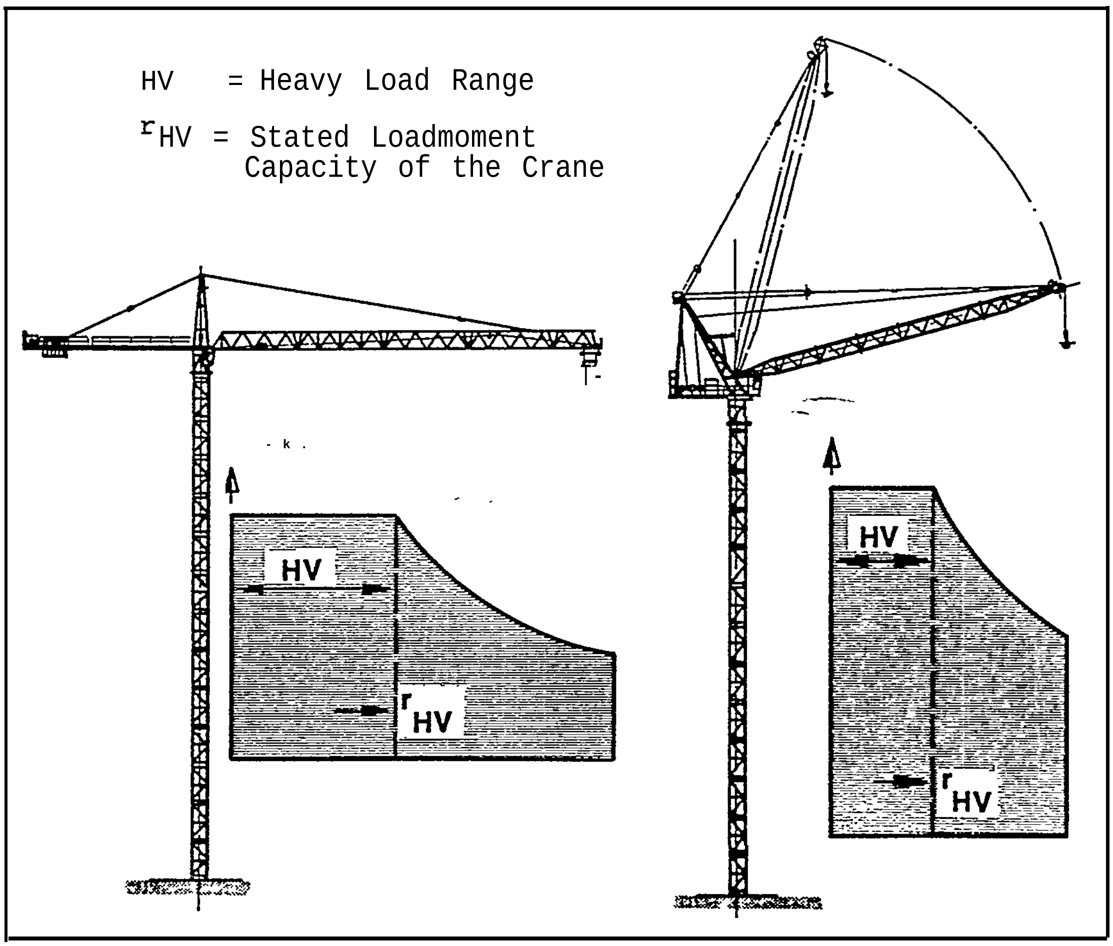


Figure 25: Loadmoment ranges of typical tower cranes

safety equipment. The cut-off figures for automatic control are based on a three-part design philosophy: <1> a crane must pick up and carry its capacity-chart load; <2> at any point between 103% and 109% of its capacity-chart load the crane may cut out; and <3> at 110% the crane will finally cut out, come what may. These margins do not represent an “overload” as such -- the crane is built with these percentages in mind. In fact DIN 15018 and FEM 83 specify exactly these margins.

The loadmoment figures for a crane are given metrically in mt (meter tons); in the U.S. the unit used is the ft kip. To calculate the rating of a tower crane it is necessary to know its capacity at various radiuses. The table and the calculations below offer one example:

	Lift capacities in lbs			
Lift Radius	Jib lenqth (maximum hook reach)			
	98.4 ft	131.2 ft	147.6 ft	164.0 ft
0 - 59.0 ft	22 000	22 000	22 000	22 000
65.6 ft	20 900	20 500	20 300	20 100
82.0 ft	16 300	16 100	15 900	15 700
98.4 ft	13 300	13 100	13 000	12 800
114.8 ft		11 000	10 900	10 800
131.2 ft		9 400	9 300	9 200
147.6 ft			8 100	7 900
164.0 ft				7 000

Figure 26: Example of a Capacity Chart

Two calculations show how the ratina of a crane with these capacity figures would be calculated.

<u>Calculation 1</u>:

The short-jib version of the crane gives the following figures. At the inner radius (between O and 59 feet), the crane-has a capacity of 22 000 lbs. Its loadmoment (loadmoment = radius x capacity) is thus:

$$\frac{59 \times 22\,000}{1000} = 1298 \text{ ft kips}$$

At its extreme radius (98.4 feet) the figure is much the same:

$$\frac{98.4 \times 13\,000}{1000} = 1279 \text{ ft kips}$$

Thus this version of the crane rates at roughly 1300 ft kips.

Calculation 2:

The long-jib version of the crane, because the jib itself is heavier, produces a slightly reduced figure at the outermost range, but the same figure in the heavy load range:

$$\frac{59 \times 22\ 000}{1000} = 1298 \text{ ft kips}$$

$$\frac{164 \times 7\ 000}{1000} = 1148 \text{ ft kips}$$

Thinking conservatively, the manufacturer will thus rate the crane at 1150 ft kips. In fact, the equivalent metric figure is handier here -- 160 mt.

This rating system is important. It deviates radically from the usual American way of rating cranes~ but it must do so to account fully for the particular performance features of the tower crane. This may be confusing for the American crane-user, but, unfortunately, there is no simple way of comparing the ratings of cranes that operate in essentially different ways.

6. HOW IT WORKS -- TOWER CRANE PRACTICE

6.1. System Crane Components

Tower cranes, for historical reasons outlined earlier, are system cranes. Figure 27 shows the components in a "system."

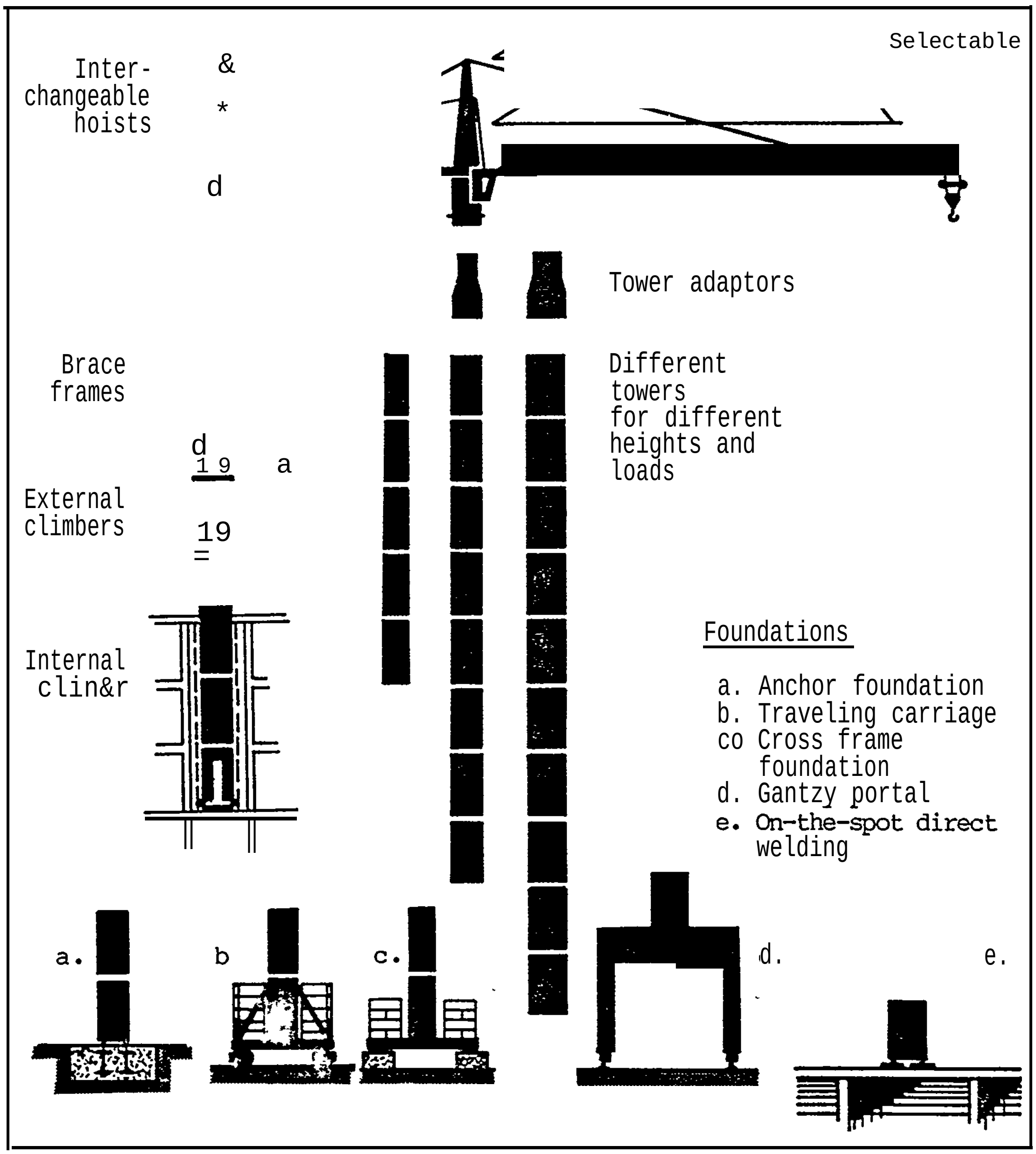


Figure 27: Elements in a tower crane system

6.2. Modes of Installation -- Some Examples

Figure 28 shows some common shipyard installations.

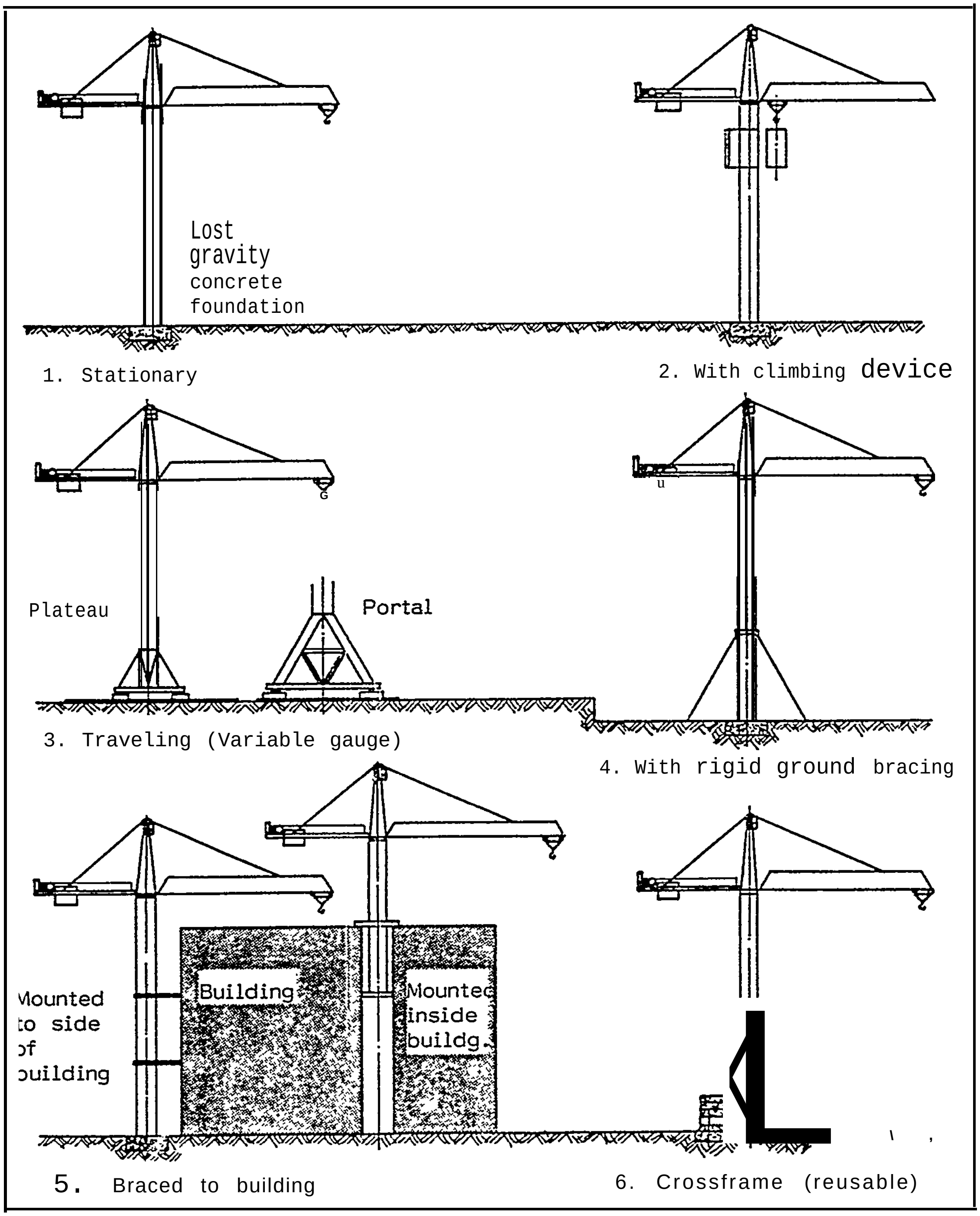


Figure 28: Common tower-crane installations

6.3. Climbing

The ability of a tower crane to climb offers the engineer interesting possibilities. Figure 29 shows the trick in action.

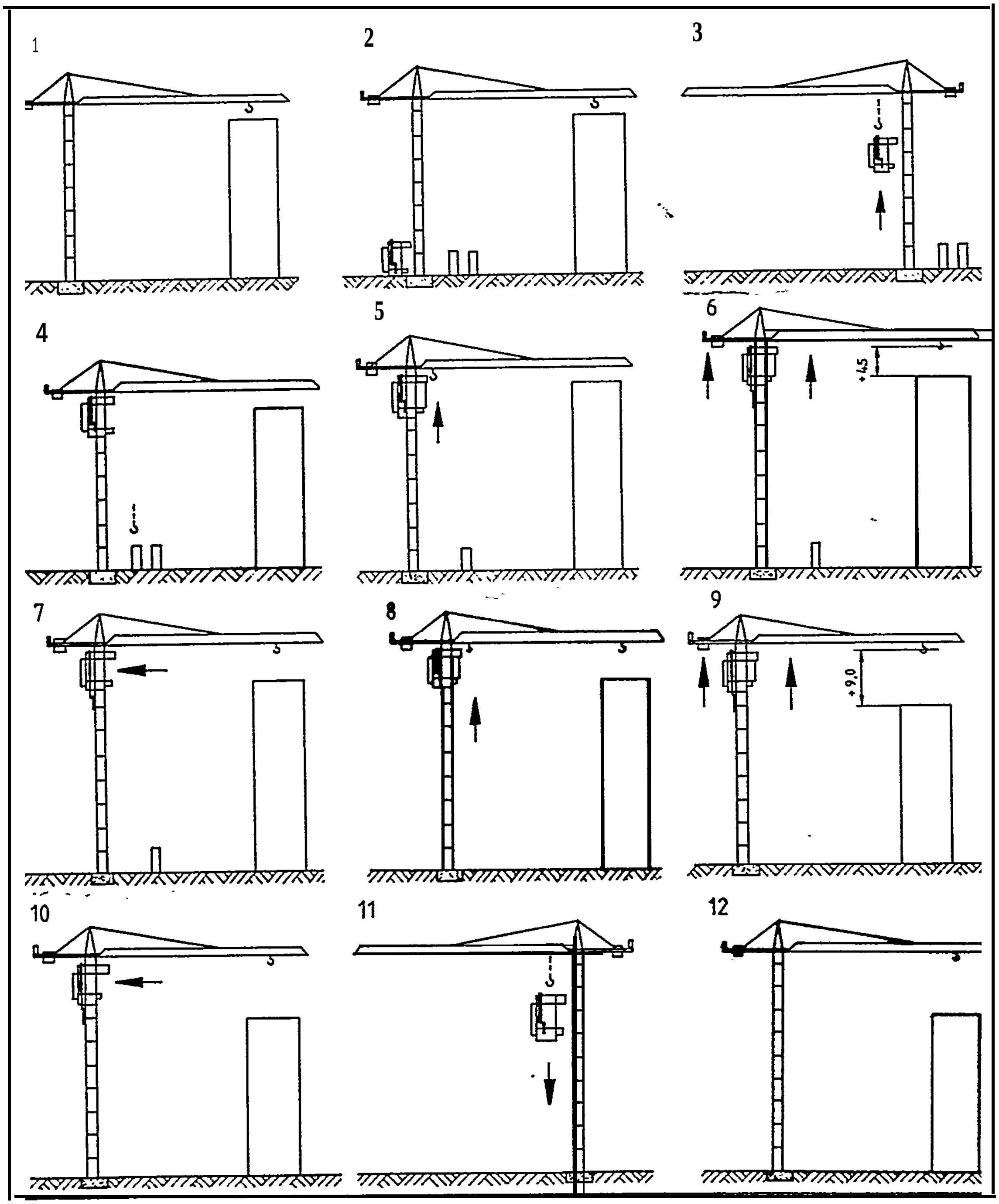


Figure 29: Steps in a tower crane's "self-climbing" procedure

6.4. Basic Operation -- Summary

All the normal operating alternatives available on other types of crane are also available on tower cranes. Prime movers, gearing systems, control systems -- these and other variables are not affected by the inherent design of the tower crane. Nor is the actual operation of a tower crane radically different from the operation of any other kind of crane. The tower crane has a different "feel," and works within different parameters~ but, in general, it is a crane like any other. Its special operating features:

- System designed components
- Extreme flexibility of installation
- The unique ability to climb

give the tower crane, however, a competitive edge in many day-to-day problem situations.

7. TOWER CRANE APPLICATIONS IN DOCKYARDS

A tower crane is a "Jack-of-all-trades ," but, unlike the proverbial Jack, it is the master of all trades too. Apart from very heavy liftsl there are few dockyard applications where a tower crane would be an inappr,opriate tool. Although no attempt is made to offer a complete catalogue, the illustrations on the following pages offer a good overview of the kinds of uses shipbuilders worldwide have found for the tower crane.

7.1. Temporary vs. Permanent Applications

One advantage of the tower crane is its portability. Section 8.1.4. presents this feature in detail. Given that a tower crane can be relocated (or even hired) to tackle a specific short-term problem, temporary installation offers a number of interesting applications. But first a word about foundations. Where a rigid structure, such as the deck of a ship or the girders of a rig are already in placer foundation plates or foundation "studs" can be welded in place, allowing quick, economical installation. (See Figure 300)

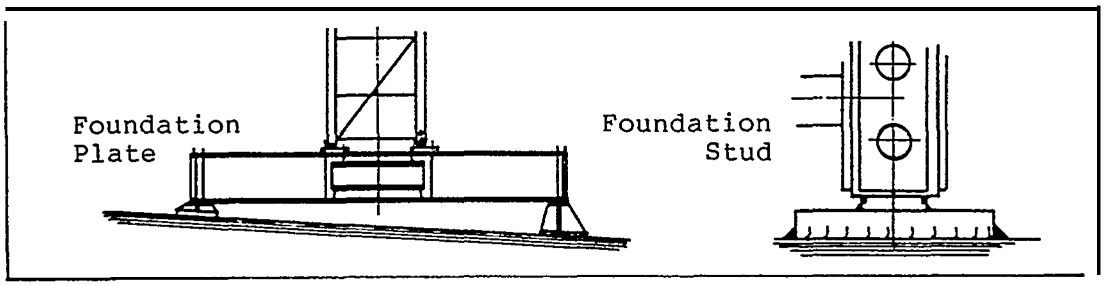


Figure 30: Foundation plates or "studs" direct-welded to decks

Figures 31 and 32 show luffing tower cranes in such situations. Considerable savings can be made by the judicious placing of a tower crane during fitting out. Removing the crane after the job presents no problems.

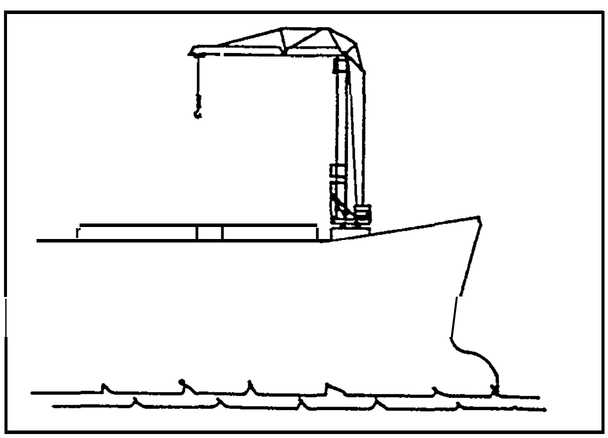


Figure 31:

Deck-mounted crane for temporary use during fitting-out

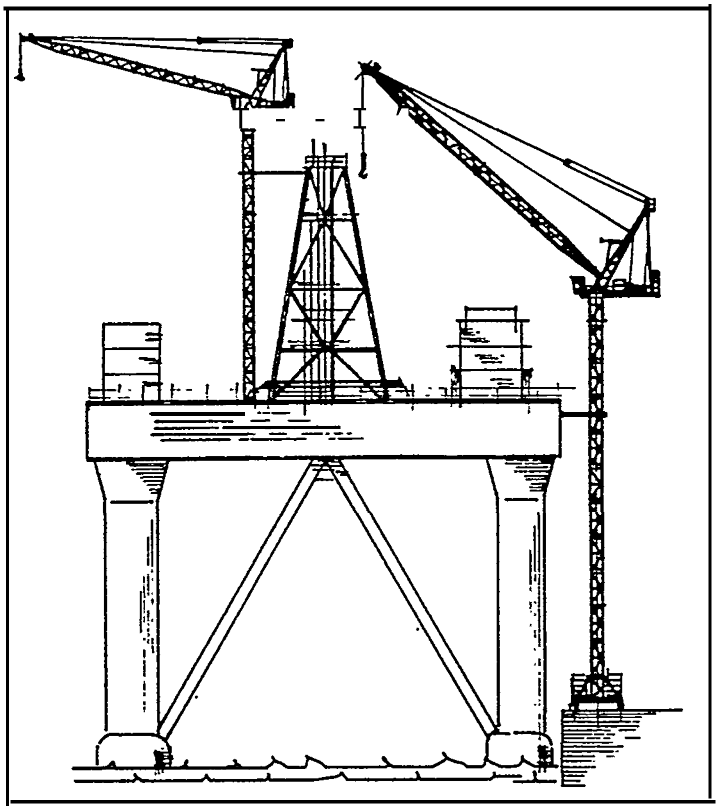


Figure 32:

Tower cranes mounted directly on and to a rig during construction

Other temporary applications would include working on a ship in a dry `berth, or working on a ship with an exceptionally tall superstructure. (See Figure 33.)

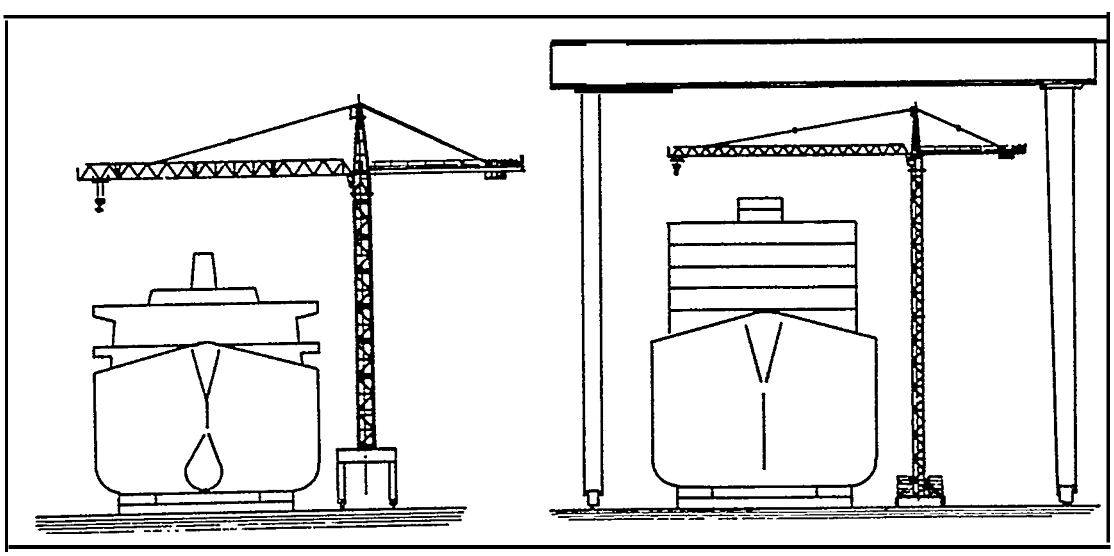
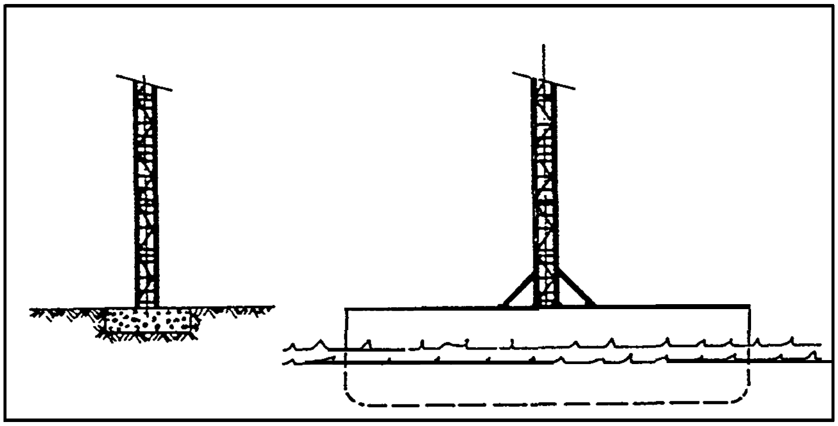


Figure 33: Temporary installations of tower cranes in dry-berth use and for use with tall superstructures

Permanent foundations may be either traveling or stationary. Stationary foundations on dry land are often of the lost-gravity, concrete type. On a rig or pontoon, some kind of rigid bracing is common. (See Figure 34.) Traveling cranes use a plateau or portal design. (See Figure 35.) However, more types of foundations exist than this study has place to describe.

Figure 34:

Permanent, stationary foundations for tower cranes



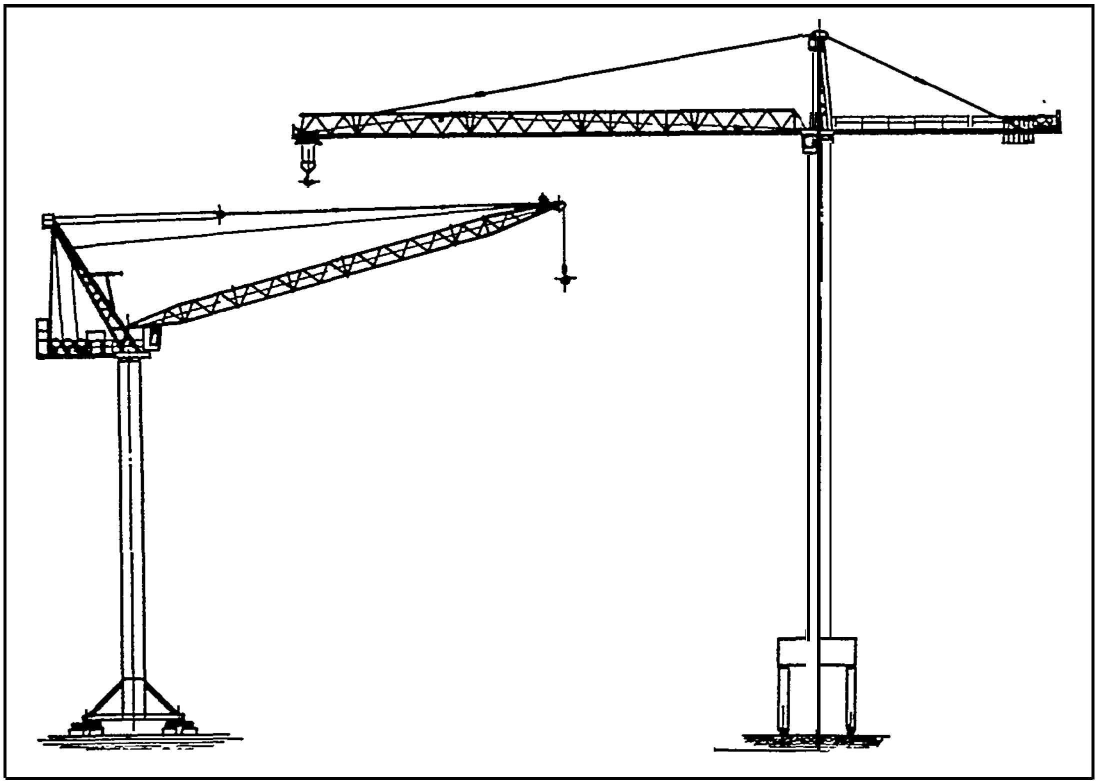
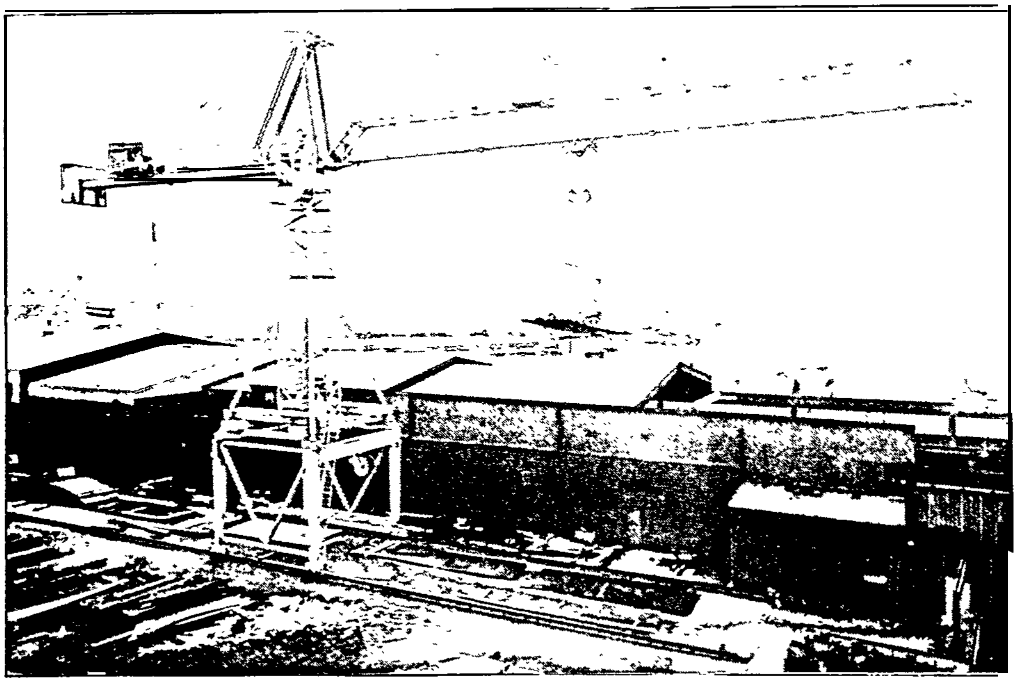


Figure 35: Traveling foundations on a portal and on a plateau undercarriage. Cylindrical pipe towers are often used for permanent installation.

7.2. Dockyard Applications: A Photofile

The collection of photographs on the next pages shows tower cranes in some of their commonest applications.

1. Working as a principal crane for small- and medium-sized ship building
2. Working in conjunction with a goliath crane
3. Working in a hull-assembly yard
4. Working in a storeyard
5. Working in teams in ship-building or refitting applications
6. Working on very high superstructures, masts, antennas etc
7. Working on very narrow quaysides
8. Working on a ship lift
9. Working on fitting-out piers
10. Working on dry-docks

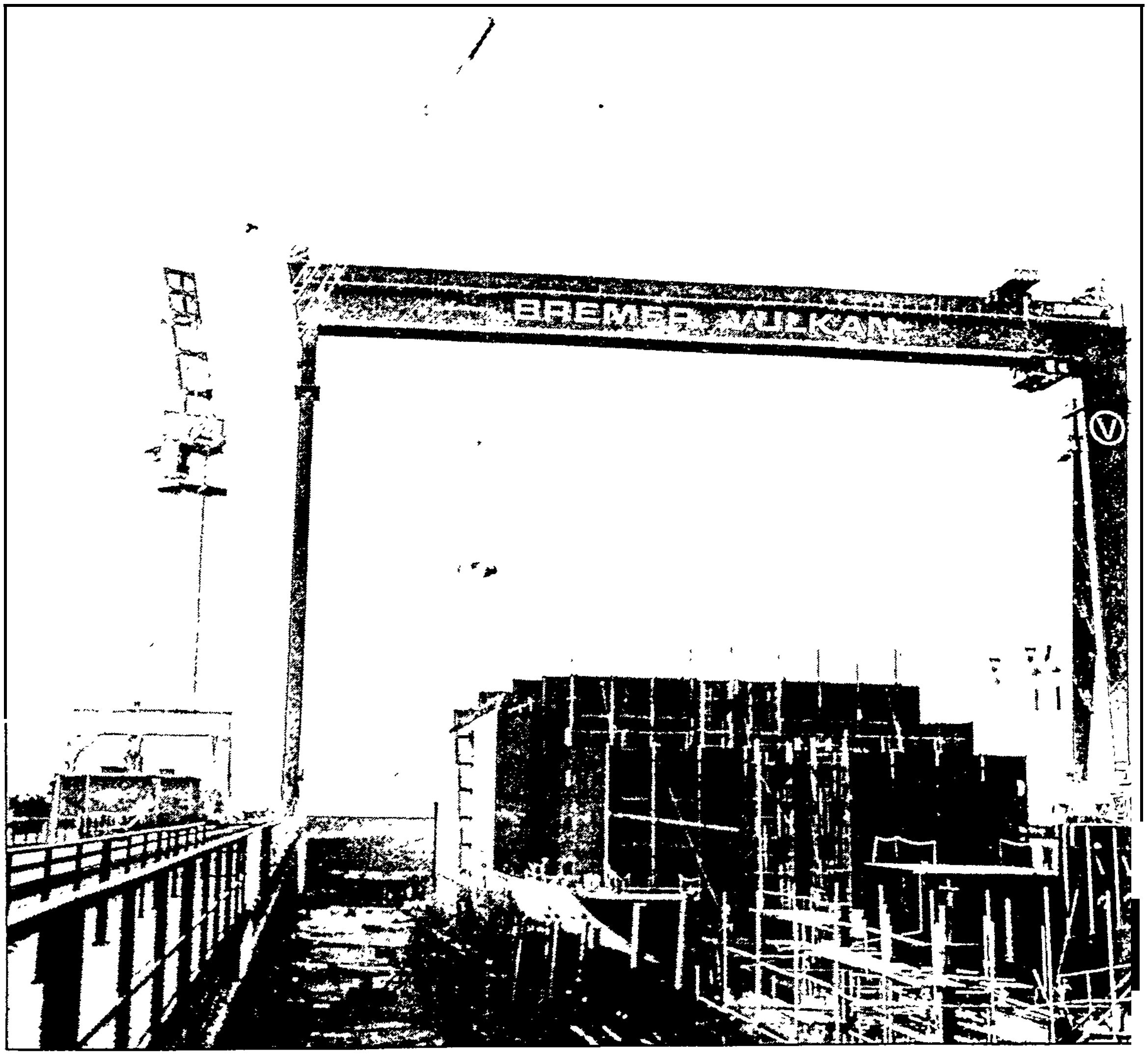


SPECIFICATION:

Crane Type:	Portal mounted, horizontal jib, traveling tower crane
Capacity:	17 600 lbs at 71 ft (= 8 t at 21.7 m) 7 050 lbs at 157 ft (= 3.2 at 48 m)
Height below hook:	49 ft (= 15 m)
Portal/rail gauge:	26.2 ft (= 8 m)
Make:	Kr$ll, Type K-154
Site:	Nystad Varv AB Shipyard, Finland

Notes: The crane serves a covered building workshop with sliding roof panels and a plate storeyard

Figure 37: Tower crane working as the principal crane in a medium-sized yard

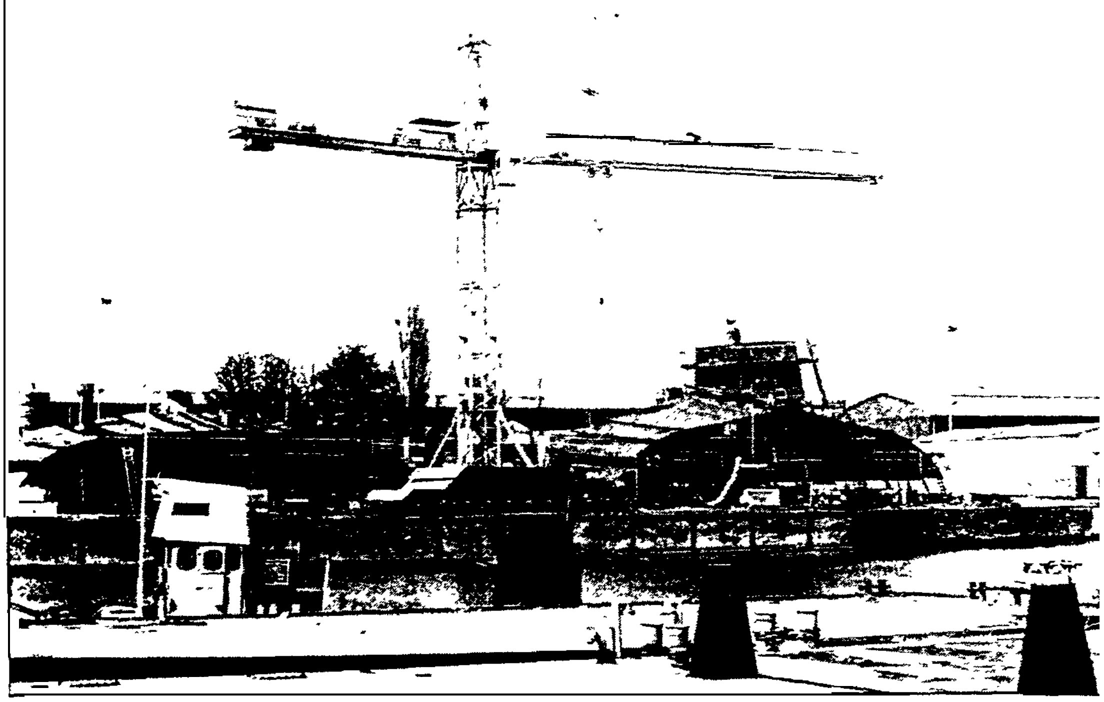


SPECIFICATION:

Crane Type:	Railed, portal-mounted with luffing-jib
Capacity:	17 650 lbs at 66 ft (= 8 t at 20 m)
	11 000 lbs at 116 ft (= 5 t at 35.5 m)
Height below hook:	131 ft (= 40 m) (at max. radius)
Portal/rail gauge:	33 ft (= 10 m)
Make:	MAN-Wolffkran
Site:	Bremer Vulkan, Bremen, W. Germany

Notes: The runway lies outside the goliath's track. The crane has a short "tail" to help bypass the goliath. Tower is eccentrically mounted for-closest proximity to the dock.

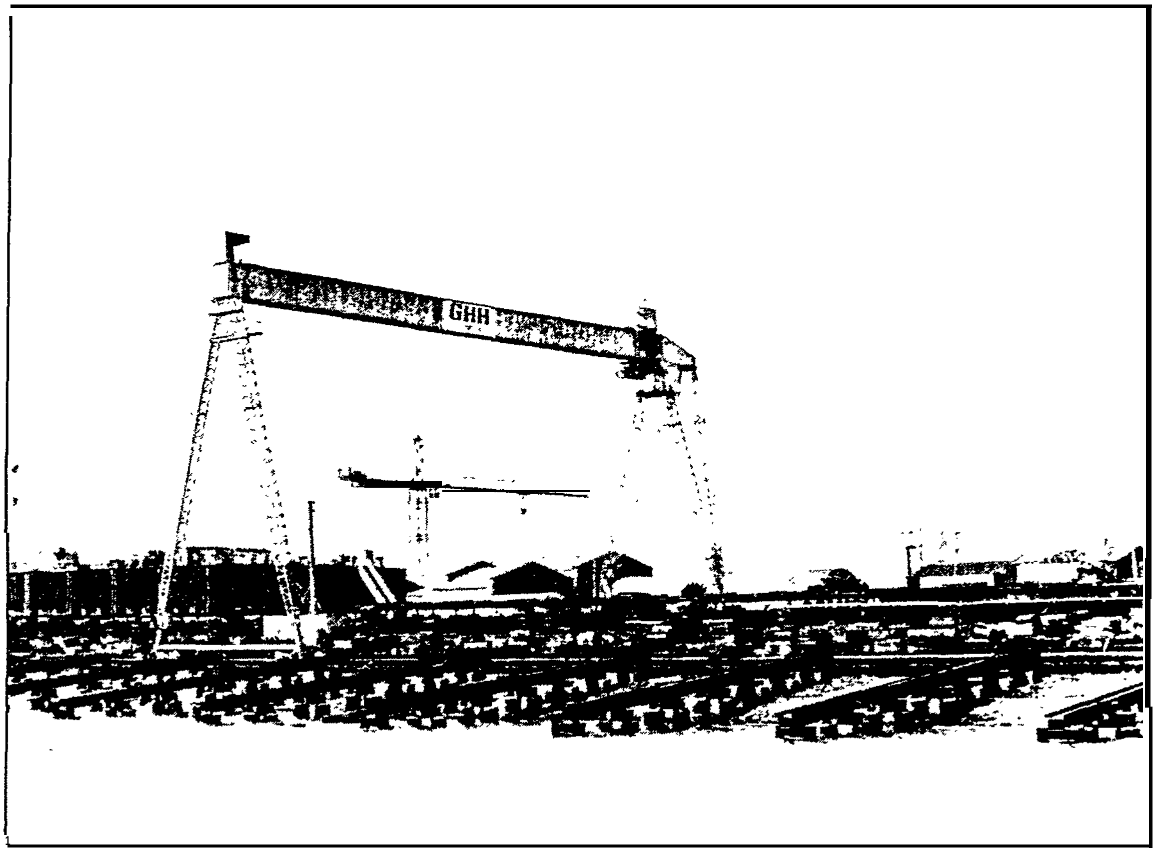
Figure 37: Luffing jib tower crane working with a goliath crane



SPECIFICATION :	
Crane Type:	Traveling, horizontal boom, top-slewing
Capacity:	22 000 lbs at 8-60 ft (= 10 t at 2.5-18.3 m) 12 800 lbs at 98 ft (= 5.8 t at 30 m)
Height below hook:	64 ft (= 19.5 m)
Portal/rail gauge:	19.7 ft (= 6 m)
Make:	MAN-Wolffkran
Site:	AG-WESER, Seebeck Yard, Bremerhaven, W. Germany

Notes: This plateau mounted traveling crane serves severa stations where hull sections are assembled and welded The overall length of track is 600 ft.

Figure 38: Tower crane working in a hull assembly yard

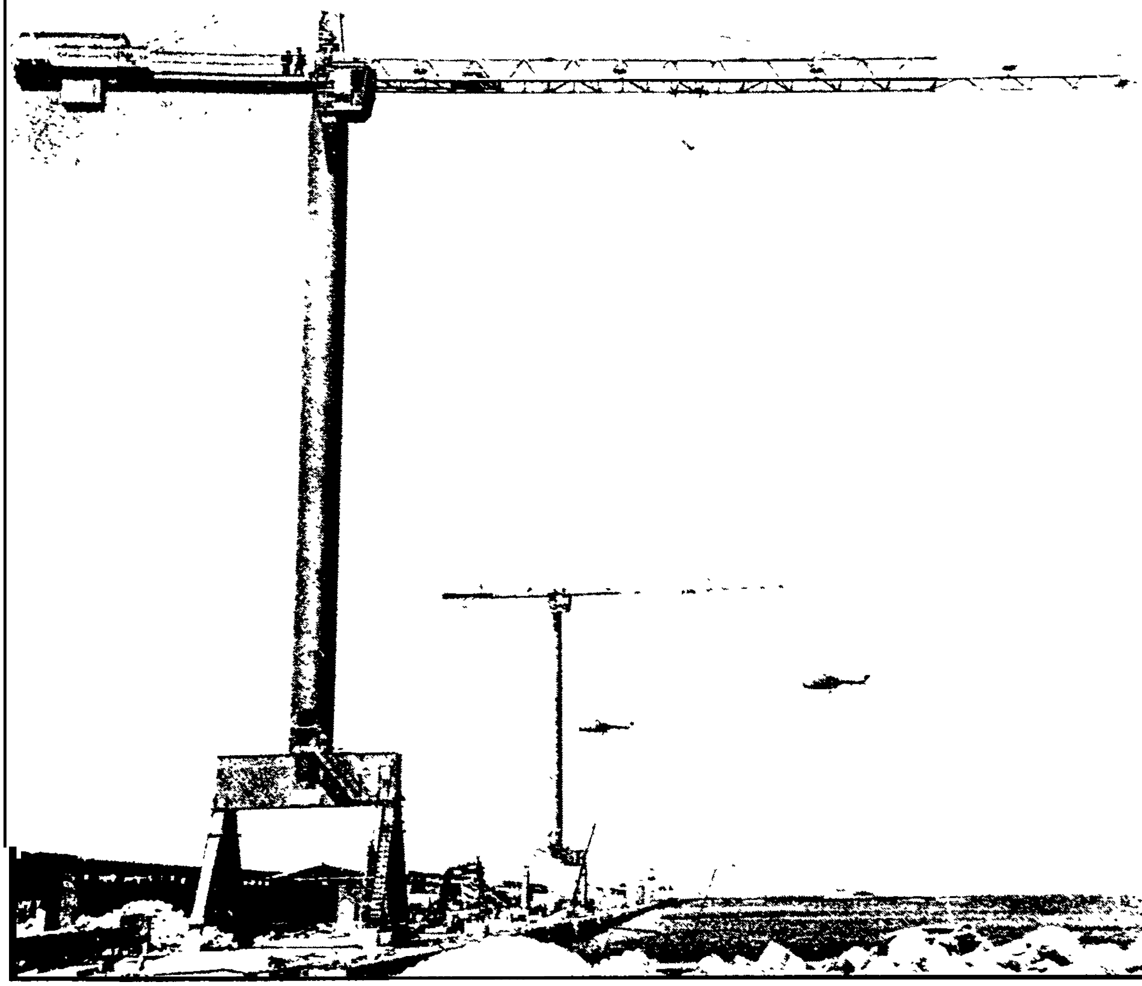


SPECIFICATION :

Crane Type:	Horizontal jib, top slewing
Capacity:	26 500 lbs at 59 ft (= 12 t at 18 m)
(4 falls)	14 550 lbs at 98 ft (= 6.6 t at 30 m)
	7 050 lbs at 164 ft (= 3.5 t at 50 m)
	(With 2 falls, capacity is half)
Max Speed:	3 300 lbs at 328 ft/min (= 1.5t at 100m/min)
(2 falls)	6 600 lbs at 206 ft/min (= 3 t at 63 m/min)
	13 230 lbs at 115 ft/min (= 6 t at 35 m/min)
	(With 4 falls, speed is half)
Height below hook:	79 ft (= 20 m)
Portal/rail gauge:	19.7 ft (= 6 m)
Make:	MAN-Wolffkran (Type WK 192/226 SL)
Site:	GHH - Blexen Yard, Unterweser, W. Germany

Notes: Tower crane with an unusually low height under hook (79 ft). The yard makes dry docks. The crane is working in the plate storeyard.

Figure 39: Tower crane in storeyard use

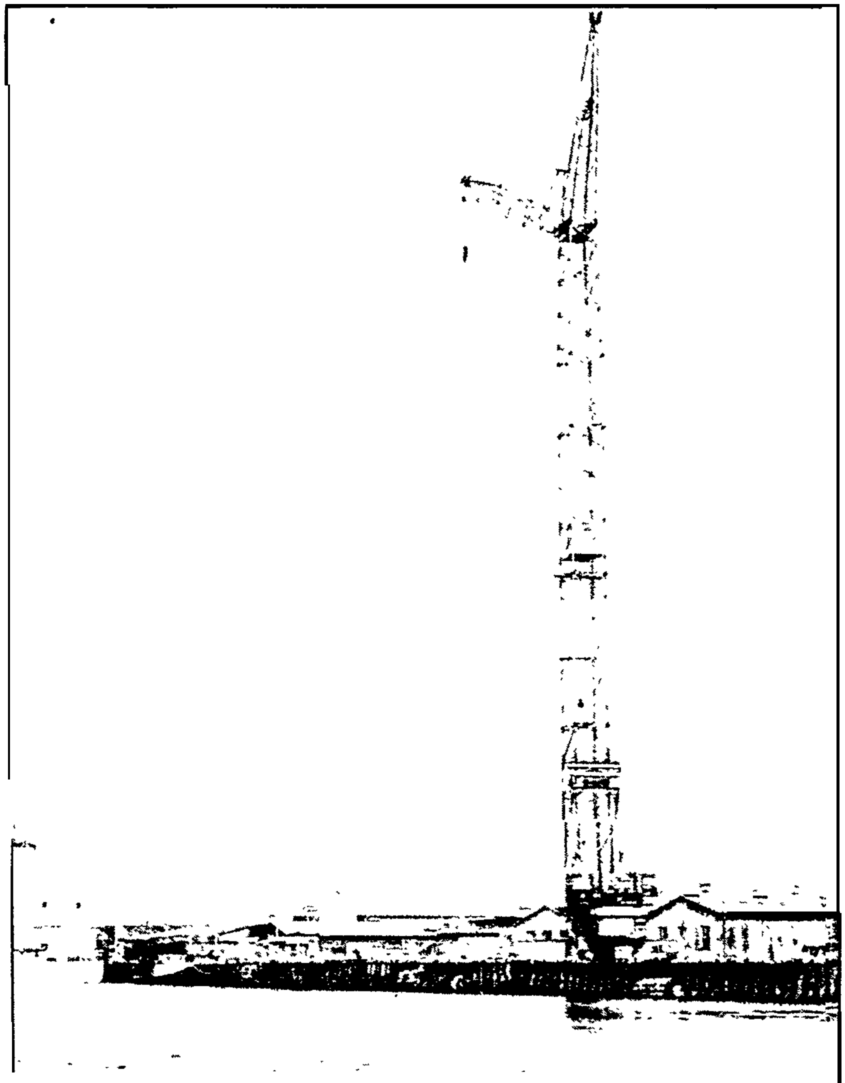


SPECIFICATION :

Crane Type: Traveling, horizontal jib, top slewing
Capacity: 17 650 lbs at 57 ft (= 8 t at 17.3 m)
15 000 lbs at 66 ft (= 6.8 t at 20 m)
6 600 lbs at 131 ft (= 3 t at 40 m)
Height below hook: 131 ft (= 40 m)
Portal/rail gauge: 33 ft (= 10 m)
Make: MAN- Wolffkran (1985)
Site: Gibraltar Shipyard, Gibraltar

Notes: The picture shows 2 of a set of 5 identical cranes. These 2 are working on a repair and fitting-out jetty. The track is 1300 feet (400 m) long. The 2 cranes can conduct a combined lift.

Figure 40: Fitting-out and repair cranes working in teams

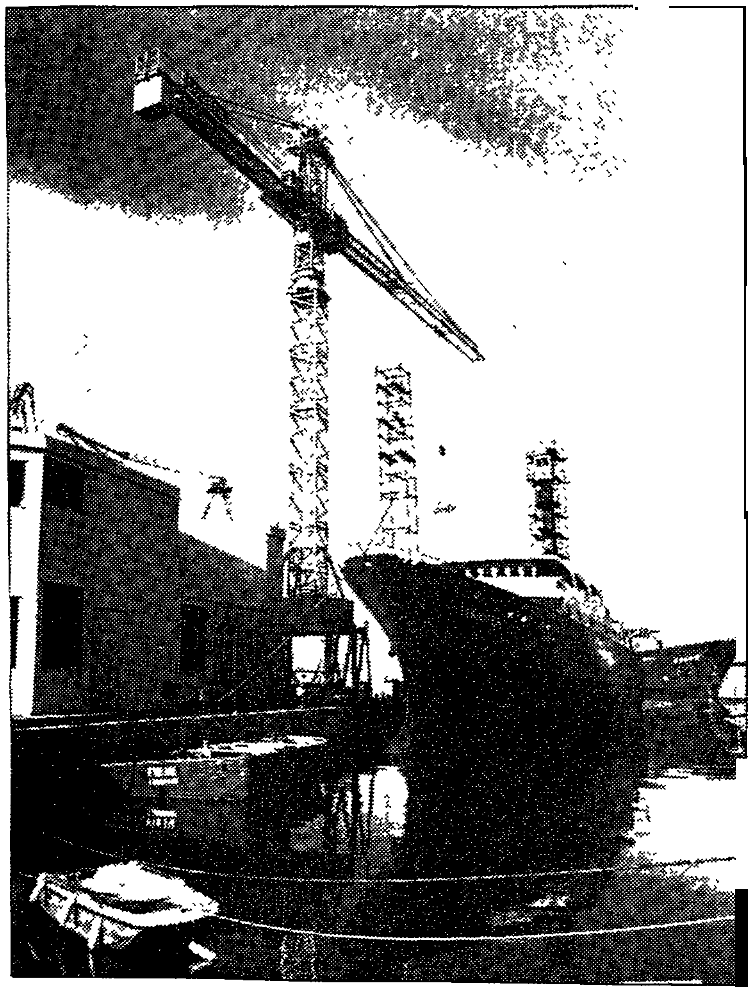


SPECIFICATION:

Crane Type: Stationary, luffing-jib tower crane
Capacity: 13 200 lbs at 56 ft (= 6 t at 17 m)
6 600 lbs at 135 ft (= 3 t at 41 m)
Height below hook: 164 ft (= 50 m)
Make: Peiner AG (Type T 125), 1970
Site: Port of Emden, Nordsee-Werke, W. Germany

Notes: The extreme height of the hook is available for special fittinq-out duties involving reaching through high superstructures, setting masts and antennas, etc.

Figure 41: Tower crane for working on very high superstructures

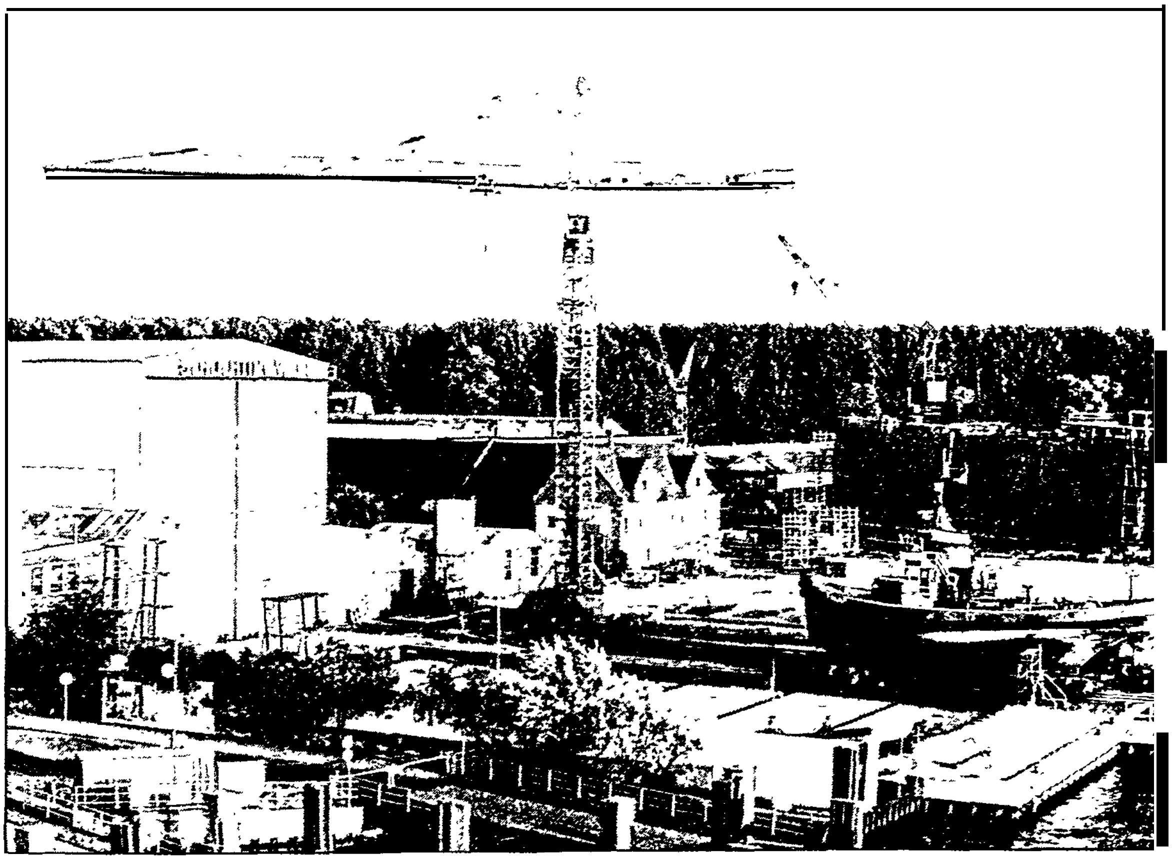


SPECIFICATION :

Crane Type: Traveling, portal-mounted, horizontal jib
Capacity: 13 200 lbs at 39 ft (= 6 t at 12 m)
3 500 lbs at 131 ft (= 1.57 t at 40 m)
Height below hook: 102 ft (= 31 m)
Portal/rail gauge: 16 ft (= 5 m)
Make: Comedil, Type MCA 551
Site: Rimini, Italy

Notes: Tower cranes are able to travel in extremely restricted" spaces. The dockside here is only a few feet wider than the portal.

Figure 42: Tower crane operating in highly restricted conditions

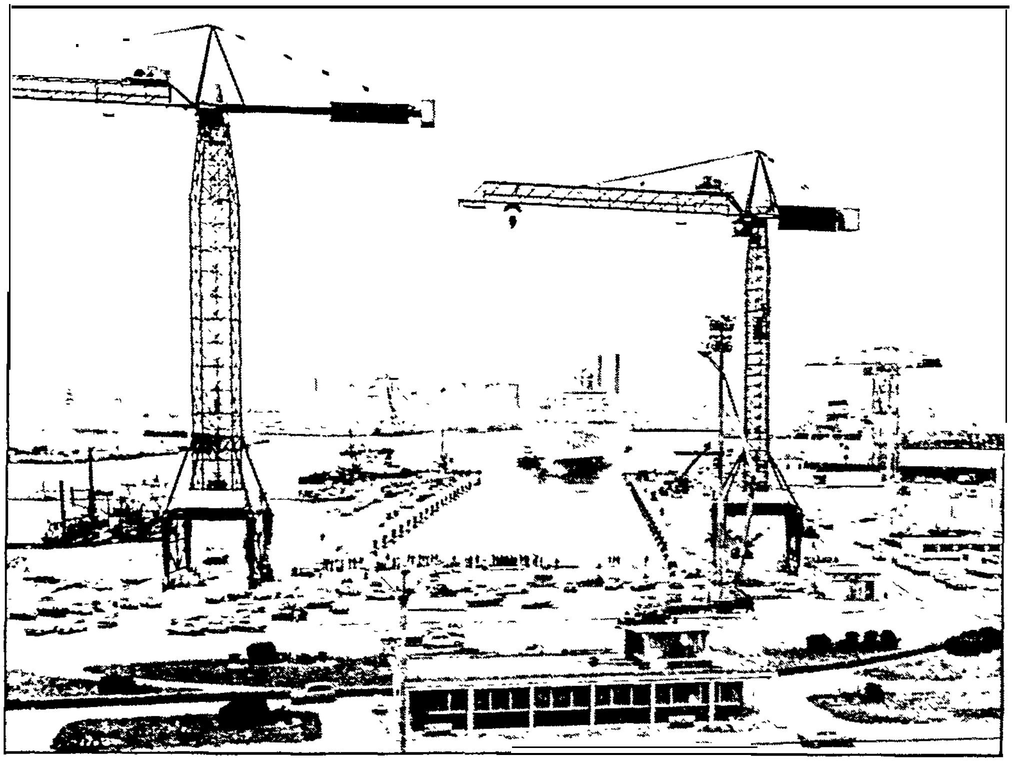


SPECIFICATION:

Crane Type:	Horizontal jib, top slewing, stationary
Capacity:	7 720 lbs at 119 ft (= 3.5 t at 36 m) 22 000 lbs at 45 ft (= 10 t at 14 m)
Height below hook:	130 ft (= 40 m)
Portal/rail gauge:	19.8 ft (= 6 m)
Make:	Liebherr, Type 120 C
Site:	Schlichting Shipyard, Travemunde, W. Germany

Notes: The crane serves the shiplift area and frontside of the covered building shop

Figure 43: Tower crane working on a ship lift

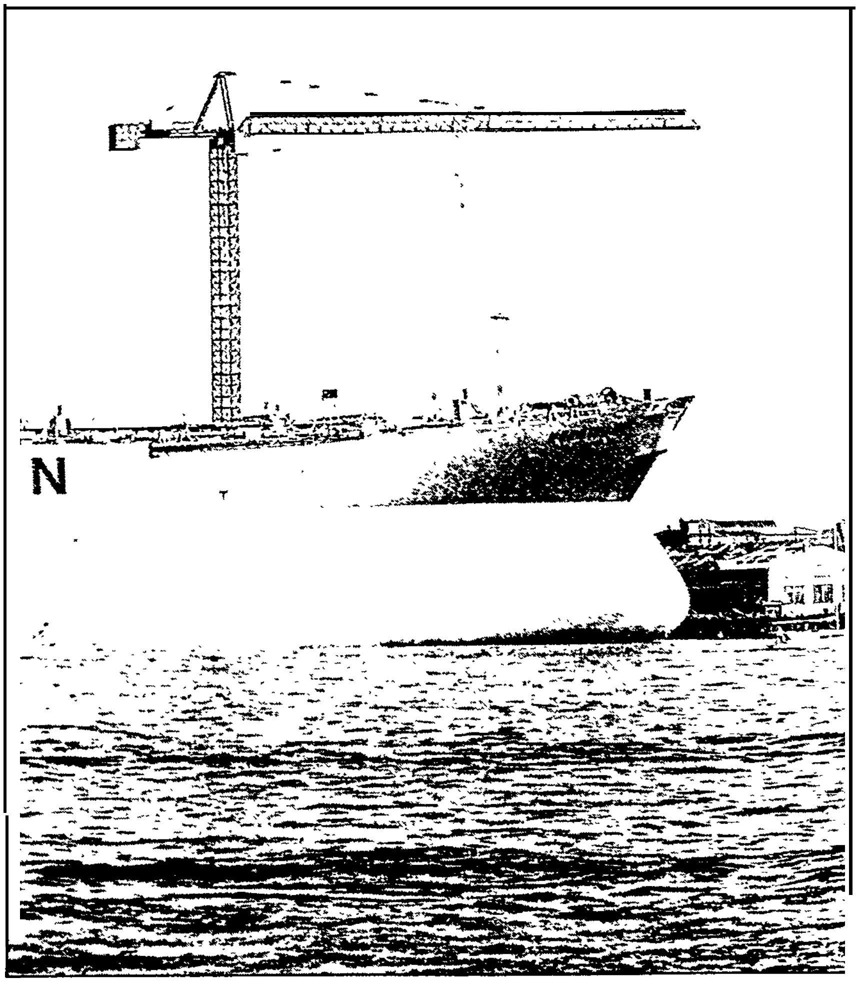


SPECIFICATION:

Crane Type:	Portal-mounted, horizontal-boom, traveling
Capacity:	88, 200 lbs at 66 ft (= 40 t at 20 m) 35, 300 lbs at 164 ft (= 16 t at 50 m)
Height below hook:	180 ft (= 55 m)
Portal/rail gauge:	33 ft (= 10 m)
Make:	Krtill, Type K-800
Site:	Drydock and Repairyard, Marseilles, France

Notes: Two permanently installed large series cranes mounted on special portals

Figure 44: Cranes working alongside drydocks



SPECIFICATION:

Crane Type: Top.slewing, horizontal jib, traveling
Capacity: 44, 000 lbs at 66 ft (= 20 t at 20 m)
11, 000 lbs at 262 ft (= 5 t at 80 m)
Height below hook: 262 ft (= 80 m)
Portal/rail gauge: 26.2 ft (= 8 m)
Make: Krtill, Type K-400
Site: Burmeister and Wain, Copenhagen, Denmark

Notes: Modern shipyards use a 20-ton crane for fitting out. It is adequate for all but the heaviest lifts associated with refitting complete engines.

Figure 45: Tower crane working on fitting-out pier

8. TOWER CRANES IN SHIPYARD USE

In first encountering a new model or a new type of crane in operation, the site engineer will probably watch for two main factors: <1> accuracy and safety of loadplacing and <2> speed. If these look good, other questions automatically arise. How flexible is the machine? What about environmental factors such as noise, space and safety? If such things are satisfactory and the crane is still a candidate for procurement, its cost-effectiveness will be the deciding factor. Accordingly, this chapter looks at each of these questions in turn, making comparisons with other types of cranes where these are pertinent.

8.1. Operation

In evaluating crane operation, three main factors apply: load placing accuracy, speed, and operational flexibility.

8.1.1. <u>Load Placinq AccuracV</u>

It can be assumed that load placing accuracy is enhanced for every type of crane if the driver is in telecommunication with an experienced rigger at ground level. Given that proviso, a tower crane still has certain advantages when it comes to working accurately.

First, the placing of the cabin is favorable. The driver is high up with an unobstructed view of the load path. Ergonomic studies have recently suggested that placing the driver's cabin slightly to the side improves observation, and therefore accuracy: the geometry of the crane provides one frame of reference for the load, while the driver's "angled" view provides another. (This is roughly like using two directional radio receivers to pinpoint a sender.) There seems to be a further psychological advantage if the driver does not feel he is directly in the load path. It is worth mentioning here a trend in tower-crane design that has NOT produced good results. This is siting cabins far out on the jib. (See Figure 46.) The theory is that the driver will have a "bird's eye view." This would be fine if drivers were birds, but they are not. Unlike hawks, humans make poor evaluations when looking straight downward. Further, the structure of the jib itself creates a number of blindspots. Finally, there is a safety factor. If anything goes wrong, the driver has a lot further to travel before he can safely reach the ground.

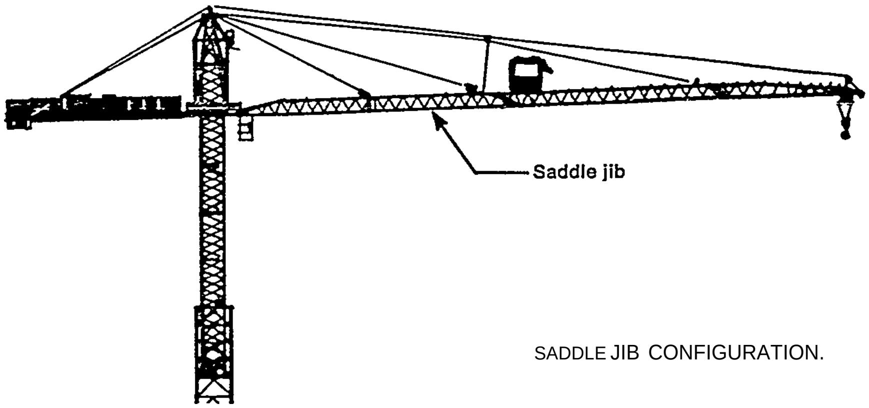


Figure 46: Poorly placed cabin mounted on jib

The second advantage of the tower crane, particularly the horizontal boom version, is the comparatively short load line. According to an old rule of thumb: "The shorter the line, the better the guidance." With two falls, or with four, load guidance with a tower crane is good.

Thirdly, a well stepped speed system has become a standard part of tower crane equipment. The system allows full speed while the load in in "clear air." As the load approaches its maximum range in any direction, or when the driver slows it down, resistorbanks or eddy-current brakes come into play, smoothly adjusting the load speed. (More on this in the next section.) This system improves the speed of operation, but it also affects accuracy since fine and critical placing movements are always made at slow, smooth speeds.

Finally, there has been a recent move to take the driver out of his cabin and locate him on the ground with a remote control console. This may appear to save on manpower, but it has a negative effect on accuracy. The driver seems to lose the "feel" of his own crane. As experienced site engineers know, there is something oddly personal about a crane; this factor, that has no other name but "feel," is an important element in driver productivity. Remote control apparently kills the productive harmony between man and machine. With the driver on the ground, distractions are more common, and accidents are more likely to occur.

Overall, an experienced tower-crane driver can place loads with remarkable accuracy. Overlapping movements, to which tower-crane operation lends itself particularly well, do not reduce accuracy, and they have a positive effect on speed and productivity.

8.1.2. Load Placing Safety

Safety and accuracy naturally go hand in hand, but when speed is added to the mixture, problems begin: the tower crane is a high-speed crane, and speed is the natural enemy of both accuracy and safety. For this reason, tower-crane designers have concentrated from the beginning on a marriage of speed and safety without compromising either. The problem looks formidable: many tower cranes operate on construction sites, often in congested city centers; construction cranes are often ten times higher than shipyard cranes, and lift chunks of prefabricated concrete that cost tens of thousands of dollars. On such sites, where public safety is a matter of supreme concernf the excellent track record of tower cranes is a matter of public record -- this is the kind of work they were originally designed for. For the shipyard the benefit is obvious -- the kind of safety required under extreme circumstances is available "off the shelf."

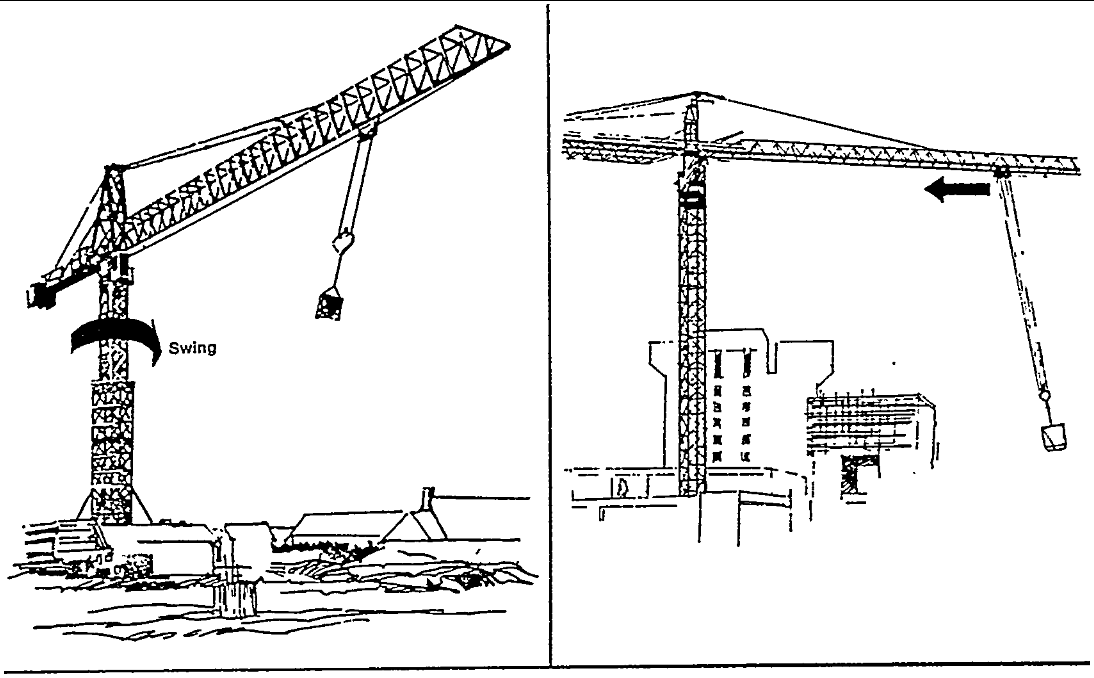
Safe load placing depends greatly on the driver's ability to correct, and if necessary reverse, unsafe movements. If things get out of hand, a load moving at high speed is comparable to a truck backing too fast into a parking lot, or a ship steaming full speed ahead into its berth -- it may be going too fast to avoid a collision. The task of the crane designer is to prevent this situation arising in the first place. Since the operating "bubble" of a crane is well defined, it is no problem to design cut-out switches that prevent actual collision, but sudden cut-out stops can be almost as dangerous as collisions. The real problem is to slow the load down smoothly, "steplessly" if possible. The load should never be snatched from the ground, nor should it approach its off-loading site at more than an easily manageable speed -- yet between these two stages it should move as fast as possible. Smooth handling is achieved by a variety of sophisticated devices:

a. Slipring motors with resistor-controlled speed steps

b. Eddy-current brakes. An <u>eddy-current brake</u> is an "anti-motor" attached directly to a prime mover. When activated, it electrically applies a magnetic field to the drive system in the counter-direction to that in which the drive is turning. This creates very smooth braking with a shock effect close to zero. Step-down speeds can be 1:10:18 (double step) or 1:10 or 1:18 (single step), or whatever is required.

c. For the smoothest possible operation, semi-stepless or stepless hydraulic drives are available. These units can even achieve shock-free reversing -- the ideal situation. The older Ward-Leonard drives, which use dc motors and an ac-dc generator for power conversion, can achieve comparable performance, but are heavier on maintenance and repair costs.

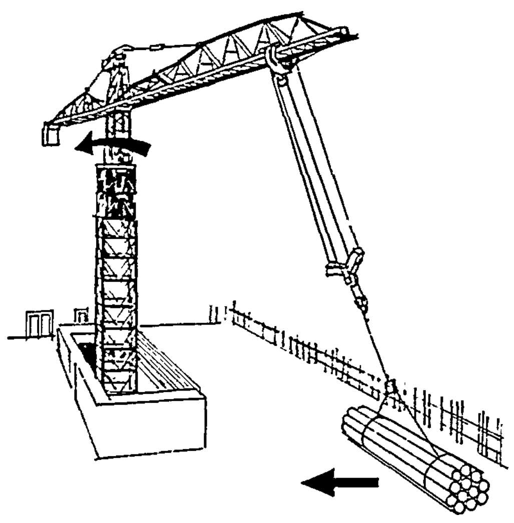
Safe loadplacing, whatever ingenuitY the manufacturer employs, is still largely in the hands of the operator. While lifting and lowering present few problems, excessively fast slewing, traversing and traveling all create horizontal inertia in the load which can quickly lead to loss of load-control. (See Figure 47.)



KEEP ALL SWING ANDTROLLEYSPEEDS LOWENOUGHTO KEEP THE LOAD UNDER CONTROL.

Figure 47: Unsafe Loadplacing

Three other situations Present common safety hazards, though none of them is unique to tower-crane operation. First, cranes are designed to lift loads, not to drag them. Dragging loads sideways is a particularly hazardous maneuver. (See Figure 48.) The second hazard occurs when a load seems to be fixed to the ground in some way -- in winter, for exampler it can be frozen in place. An attempt to jerk the load free could end in disaster. The third problem is a cluttered swing-path (See Figure 49.) Unless the swing-path is clear of obstructions and personnel, the driver should not begin any slewing movements. These cautions obviously apply to <u>all</u> crane operations; operating a tower crane does not, in principle, differ from operating any other kind of crane.



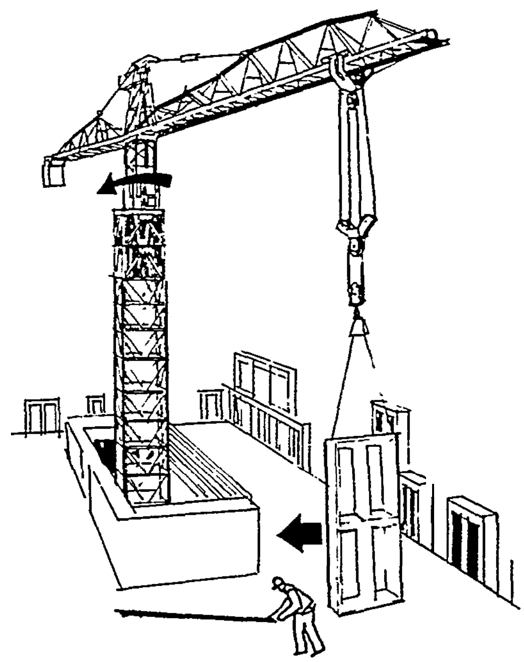
NEVERDRAGLOADS SIDEWAYS.

Figure 48:

Unsafe load moving

<1> Dragging a load sideways

<2> Attempting to "snatch" free a stuck or frozen load



KEEPTHESWING PATH CLEAR.

Figure 49:

Unsafe load moving

Swing path is obstructed by personnel or material

To summarize, high speed over great heights has always characterized tower crane operation. Because of this speed, safe loadplacing has inevitably been a top design priority. As the great sports cars show, speed and safety are not incompatible if the engineering is right.

8.1.3. Speed of Operation -- Cycle Time Analysis

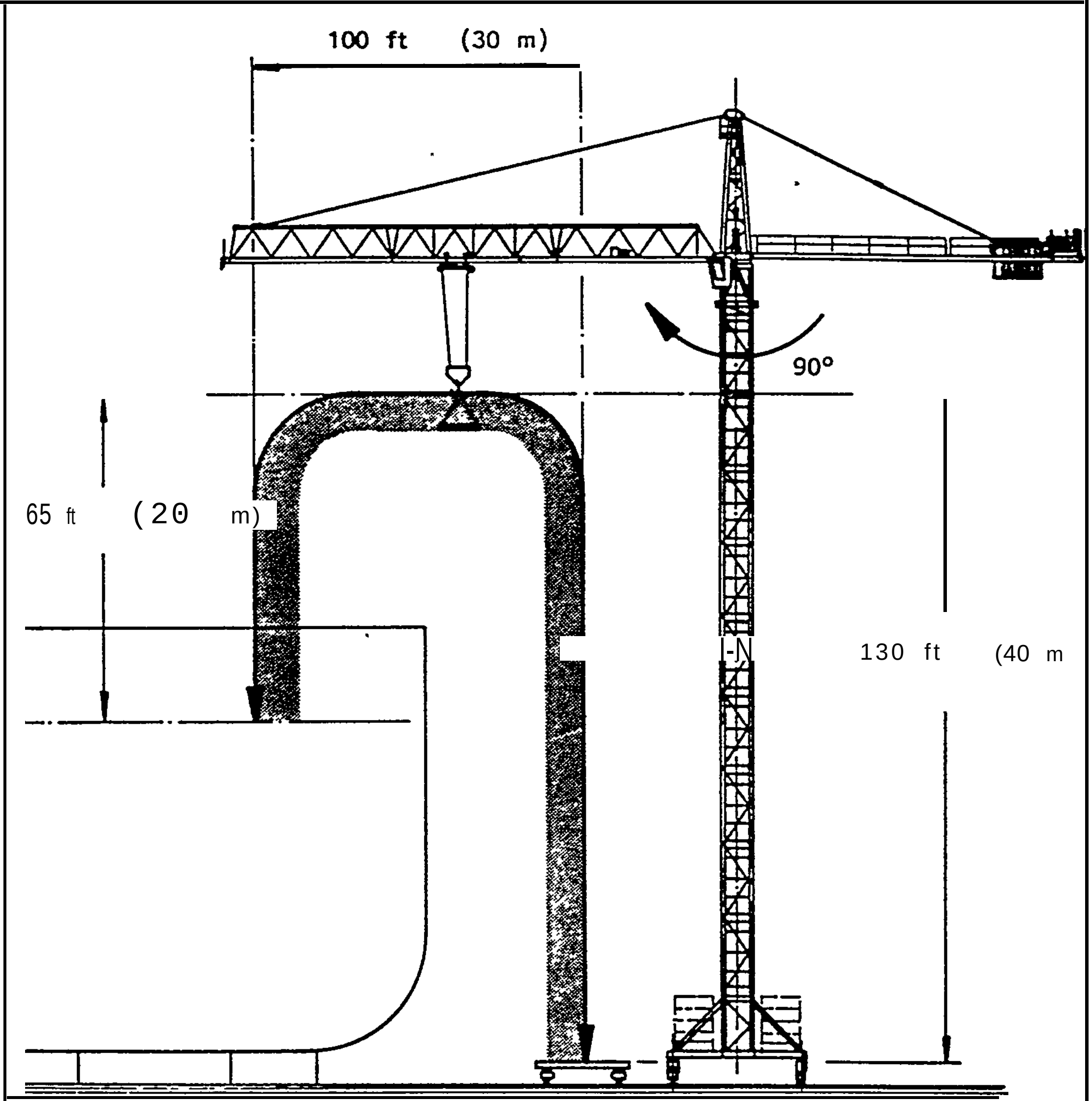
Comparing cranes is not easy. European work preparation groups have nevertheless devised a theoretical cycle for light lifts that enables the performance of several cranes to be compared. The model cycle assumes the following sequence:

1. The load is fixed to the hook in the lowermost position, ready to go
2. Required movements take place in three steps:
   a. Acceleration phase: speed increases from O to max.
   b. Main phase: most of the movement takes place
   c. Deceleration phase: speed decreases from max. to O.
3. The lift takes place as in Step 2
4. Traversing takes place as in Step 2
5. Slewing is considered as an "overlapped" movement that takes place during Steps 3 and 4
6. Lowering takes place as in Step 2
7. Unhooking the load takes a standard nominal time
8. Steps 3,4,5 and 6 are repeated, returning the hook to the lowermost position.
9. The final step is attaching the next load to the hook

A theoretical addition of 20% is made to the total time for the crane driver's "personal" needs, for possible obstacles in the load-path, for unforeseen problems in unhooking, and so on.

The model is, of course, theoretical. In practice, cycle times are up to 30% shorter because skilled operators can "overlap" not only slewing, but also traversing. Working against the cycle time, on the other hand, may be poor organization of the floor transport -- flats, trucks and so on; with reasonable logistic management, however, a four-minute cycle should be enough to replace an empty truck with a full one at the loading point. Clearing newly unhooked loads from the offloading point can also slow down operations considerably. Finally the model assumes that all loads are the same size -- in practice only 20% of loads are typically "full loads." Given these reservations, the model is a useful guide to comparative output.

On the following pages, this job-matrix is used to compare two tower cranes, a Type-1 and a Type-2 crane from the typology given earlier. The Type 1 crane has an electric motor (88 kw/120 hp) with eddy-current brakes, the Type 2 has a hydraulic drive. Both have mechanical transmission systems.



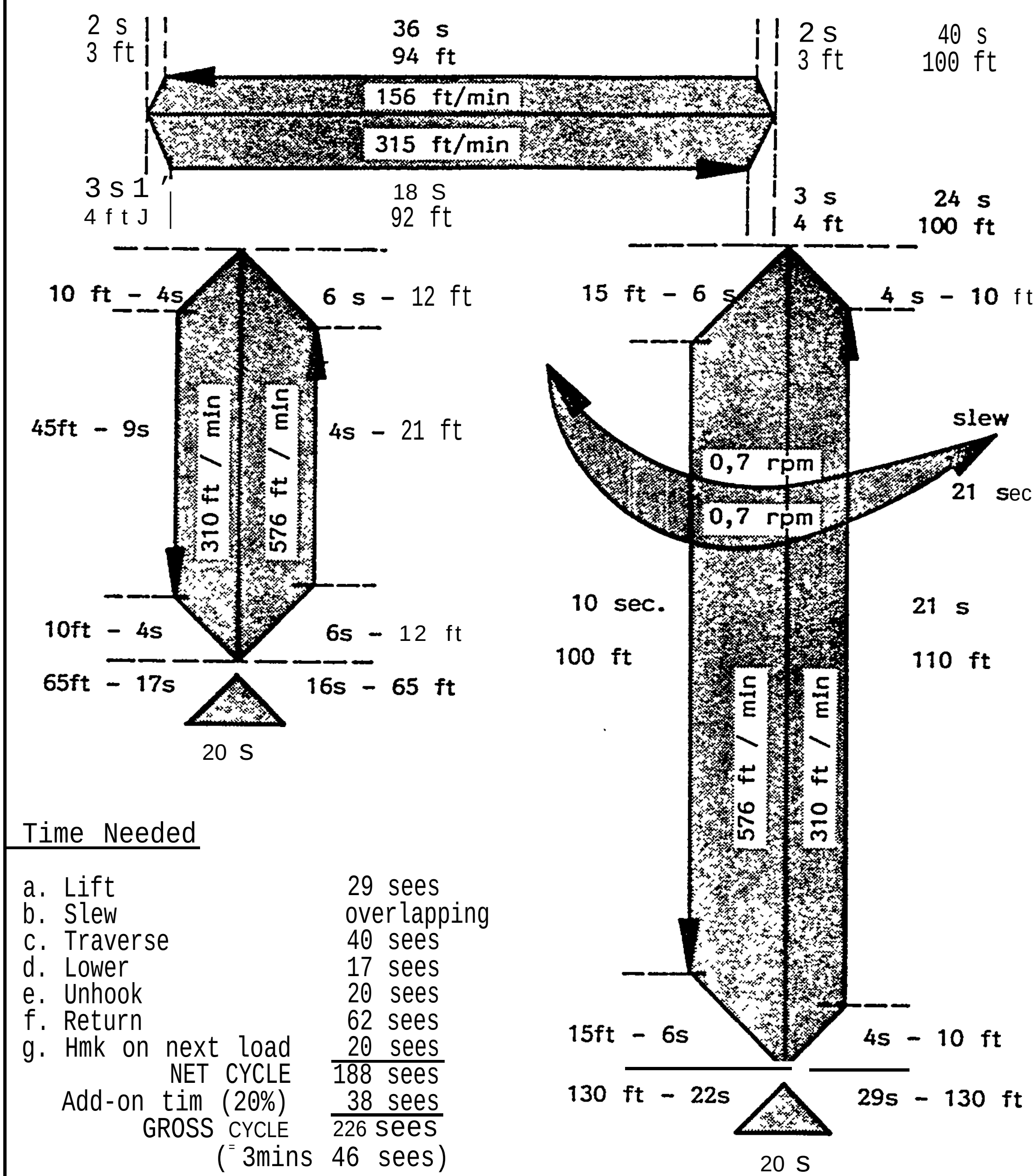
Dascription of Job

Load: 8800 lbs (4 metric tons)

Sequence:
a. Lift 130 ft (40 m)
b. Slew 90°
c. Traverse 100 ft (30 m)
d. Lower 65 ft (20 m)
e. Unhook
f. Return by same route
9" Hook on next load

Add-on time: 20%

Figure 50: Work cycle analysis for horizontal-jib, top-slewing tower crane



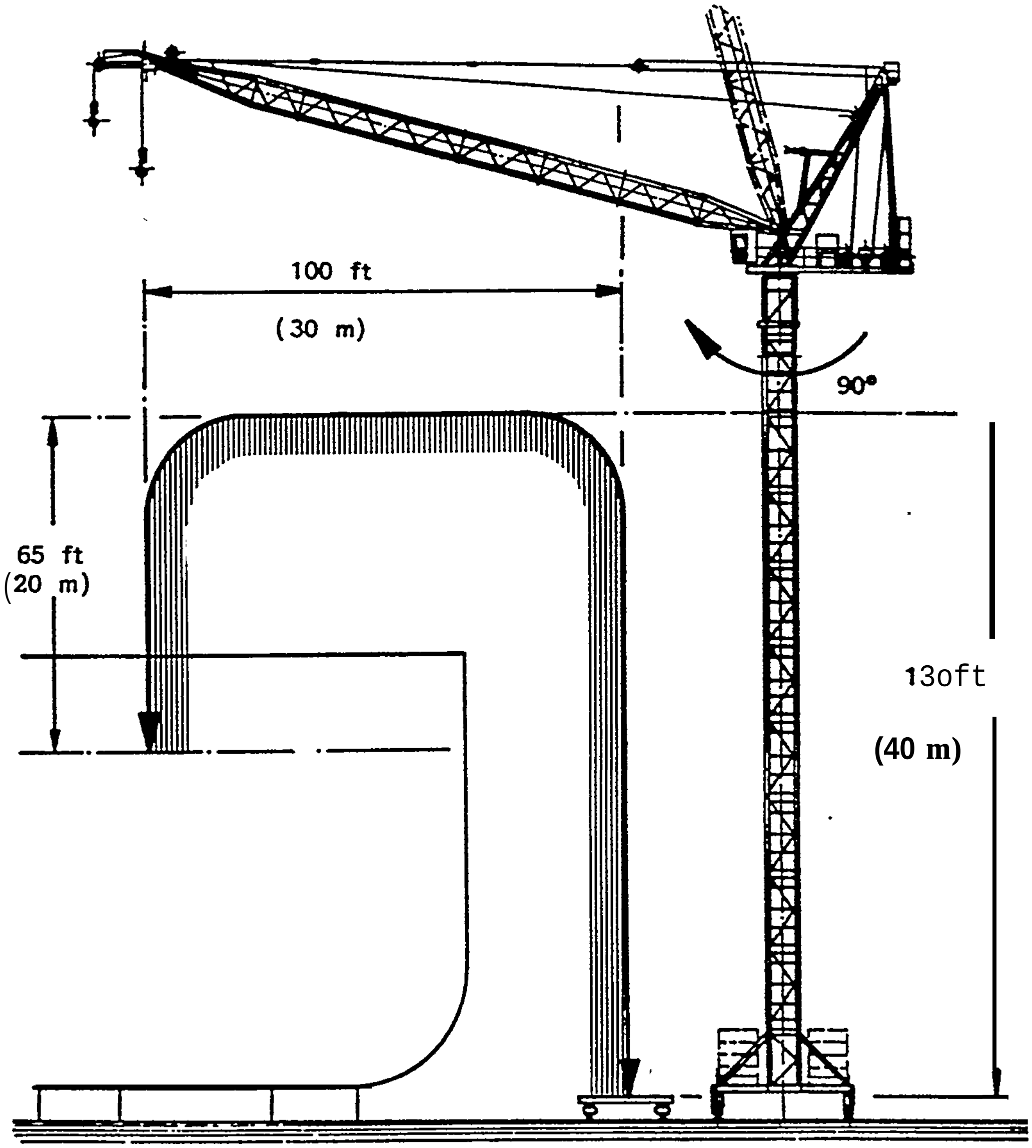
Time Needed

a. Lift	29 sees
b. Slew	overlapping
c. Traverse	40 sees
d. Lower	17 sees
e. Unhook	20 sees
f. Return	62 sees
g. Hmk on next load	20 sees
NET CYCLE	188 sees
Add-on tim (20%)	38 sees
GROSS CYCLE	226 sees
	(= 3mins 46 sees)

THEORETICAL CAPACITY: CRANE 1 (Assuming 4-minute Cycle)

Lift = 8800 lbs
Lifts per hour = 15
Lifts per 8-hour shift = 120
Work per shift = 1,056,000 lbs (480 metric tons)

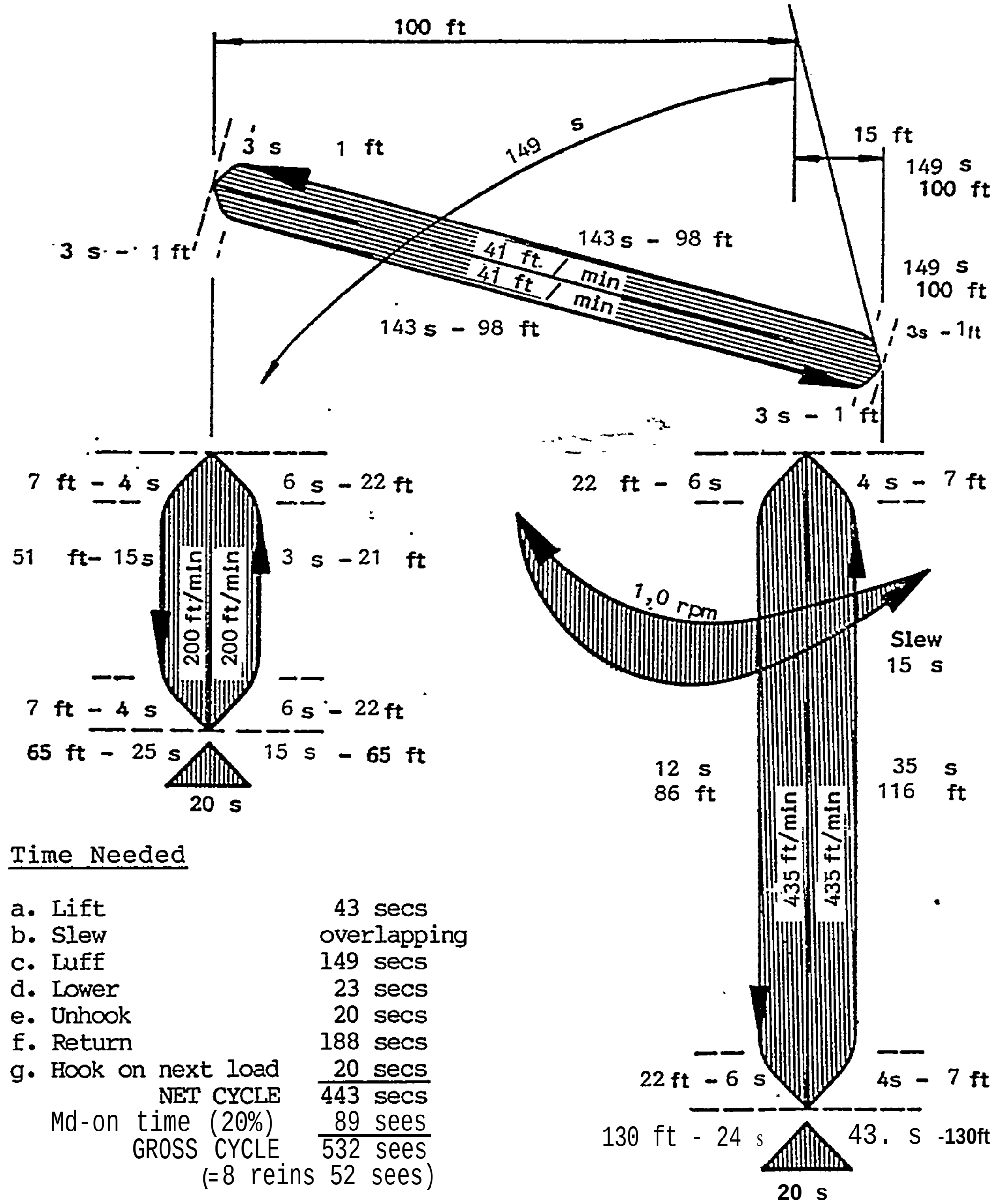
Figure 51: Work cycle calculations for horizontal-jib, top-slewing tower crane



description of Job

Load: 8800 lbs (4 metric tons)
Sequence: a. Lift 130 ft (40 m)
b. Slew 90°
c. Luff 100 ft (30 m)
d. Lower 65 ft (20 m)
e. Unhook
f. Return by same route
g. Hook on next load
Add-on time: 20%

Figure 52: Work cycle analysis for luffing-jib, top-slewing tower crane



Time Needed

a. Lift	43 secs
b. Slew	overlapping
c. Luff	149 secs
d. Lower	23 secs
e. Unhook	20 secs
f. Return	188 secs
g. Hook on next load	20 secs
NET CYCLE	443 secs
Md-on time (20%)	89 sees
GROSS CYCLE	532 sees
	(=8 reins 52 sees)

THEORETICAL CAPACITY: CRANE 2 (Assuming 9-minute Cycle)

Lift = 8800 lbs
Lifts per hour = 6.7
Lifts per 8-hour shift = 53
Work per shift= 466, 400 Ibs (212 metric tons)

Figure 53: Work cycle calculations for luffing-jib, top-slewing tower crane

Calculations for other cranes, for example for Types 3 and 4 in the typology, are not made here for reasons of space. Two principles, however, emerge from a full-scale comparison of many models. First, because of the extra weight to be shifted, a bottom-slewing tower crane is less efficient than a top-slewing model. In fact for most dockyard applications bottom-slewing models are no longer in favor. The second principle far more important: as the above calculations show, the horizontal-jib crane achieves a much better work output than the luffing-jib crane. A glance at the figures makes the reason obvious: while the horizontal-jib crane can traverse 100 feet in 40 seconds, a 100-foot luff takes well over twice as long, 93 seconds. This time deficit is doubled when the hook returns to its starting point; luffing, in fact, adds almost two minutes to the cycle. The weight of the luffing jib also requires the installation of relatively heavy prime movers, giving a poor power-work ratio. The figures are suggestive: since many smaller cranes in current operation in U.S. shipyards use a luffing jib, their inherently poor power-work ratio is worth investigation. Analysis shows that a luffing crane comes into its own only when a relatively low "tower" is required. For typical shipyard tasks involving light lifts, the speed and efficiency of a horizontal-jib top-slewing crane are strong recommendations.

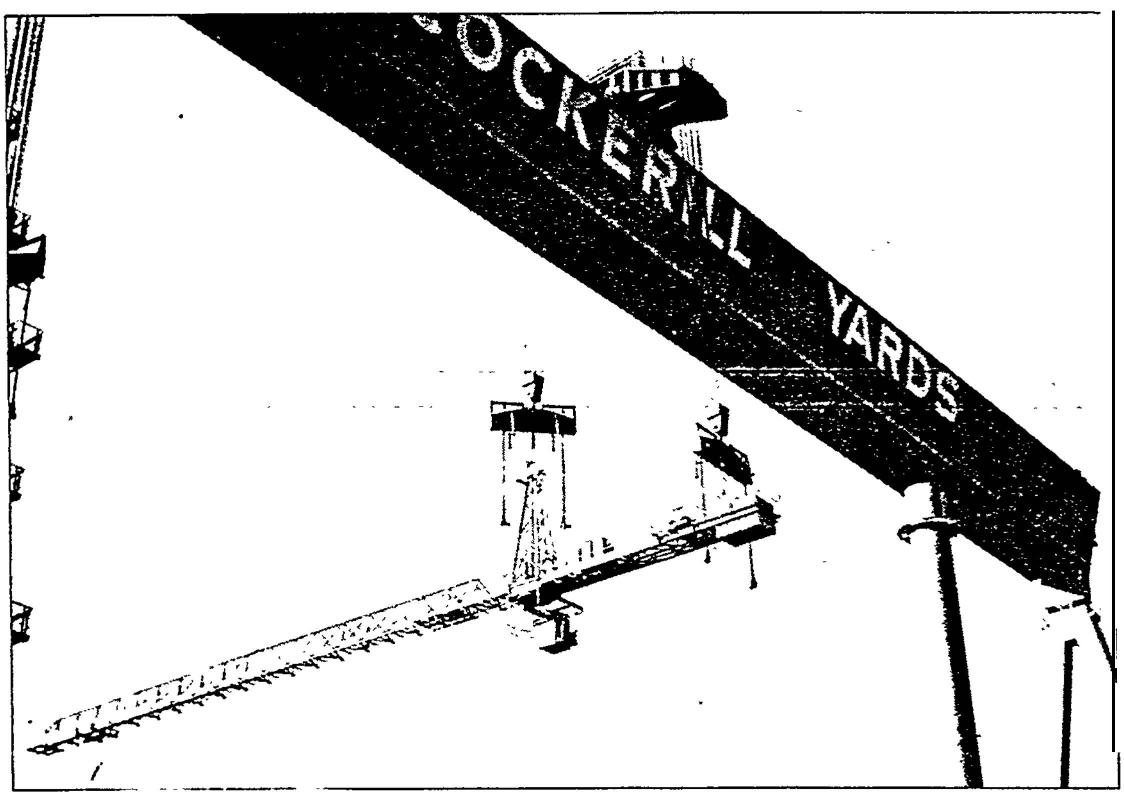


Figure 54: Slew-portion of a tower crane relocated by a goliath

8.1.4. Flexibility of Operation -- portability

If a traditional crane in any shipyard is in the wrong place, then usually nothing can be done about it. Tower cranes, on the other hand, can be relocated with surprisingly little trouble. There are limits, of course: a tower crane weighs as much as a medium sized steam-engine or a large army tank. However, given the normal proximity of a goliath, crane moving is no problem. Some tower cranes are designed to be moved in two parts; others can be moved as single units. In both cases, the counter- and center-ballast must be secured. For single unit moves, nothing more need be done to the crane beyond locking the slewing part to the tower. (The necessary accessories are available as system parts.) A time-frame of 16 hours is-typical for a two-part move. Figure 54 shows a goliath crane moving the jib of a tower crane, while Figure 55 shows a complete crane designed for a "one-shot" move, again by its "big brother" goliath.

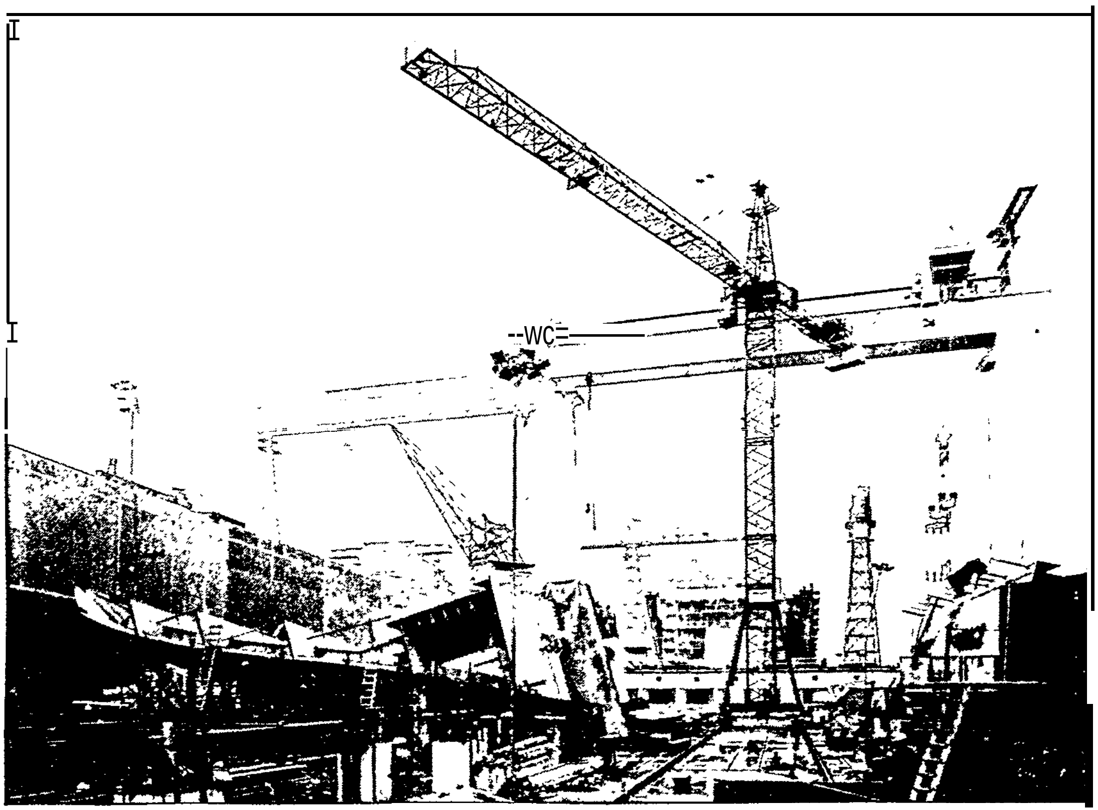


Figure 55: Complete tower crane relocatable in "one shot"

With smaller cranes full portability is one of the available options. A tower crane can, in fact, be broken down and packed

as a truck-sized load. Most of the dismantling and rebuilding operations can be carried out by the crane itself using its own power and hook. When "outside" lifting power is required, the crane will be so close to the ground that any small mobile crane -- usually available "round the corner" -- will be adequate. Figure 29 in Section 6.3. shows the steps involved in self-climbing. Self-dismantling and self-assembly follow the same principle. Figure 56 shows in diagrammatic form the steps involved in erecting a typical "fast tower" crane.

1 Basic position forerection
2 Erecting of towers
3Towerserectedand locked
4 Telescoping the towers
5 Telescoping towers with positioning of the jib
6 Readyforoperation

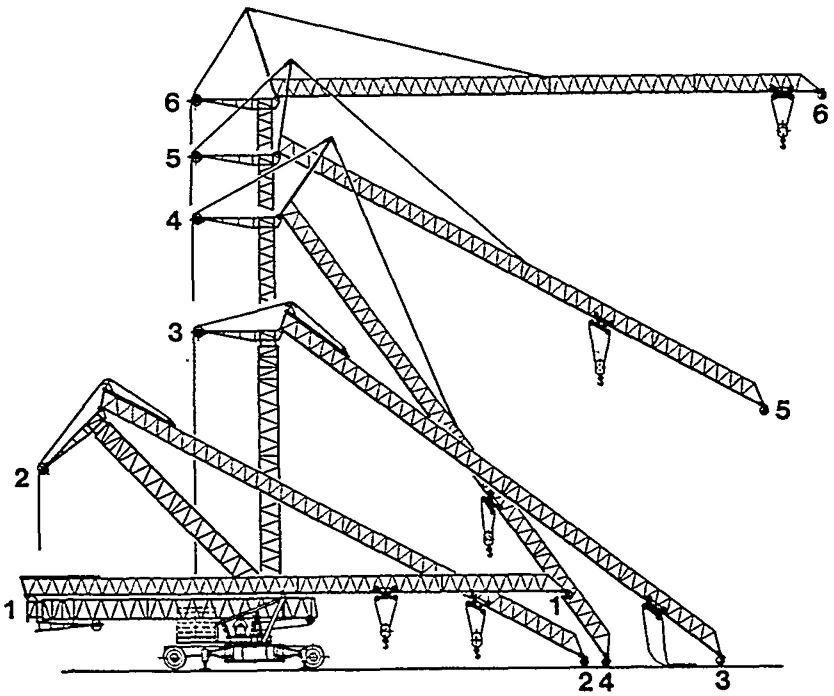
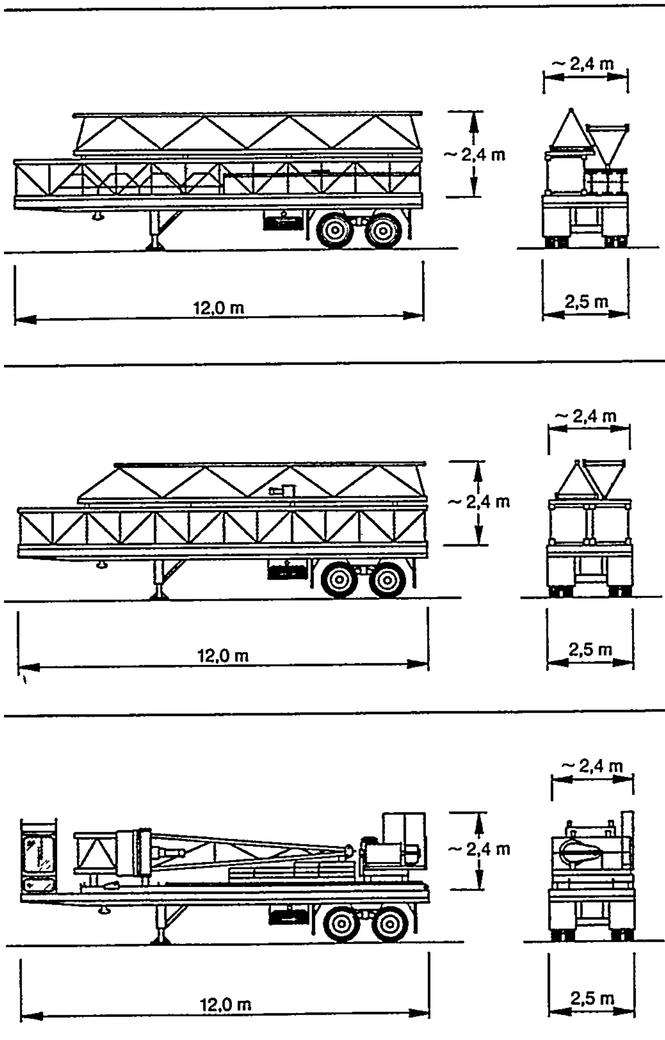


Figure 56: Erection (or dismantling) of a typical "fast tower" crane

Figure 57 gives the packing dimensions and weights involved in moving a smaller system tower crane, in this case an MAN-Wolffkran WK 62 SLC. For other makes of crane, the figures would be comparable.

/K 62 SLC — Hakenhöhe, stationär 37,5 m / Hook height, stationary 37,5 m — Ausladung 40 m / Jib radius 40 m



Kolli / Colli		Einzel-Gewicht / Single-weight (kg)	Gesamt-Gewicht / Total-weight (kg)
Turmelement / Towerelement	1xTB 12 (6,0 m)	1500	1500
Turmelement / Towerelement	1xTE 12 (6,0 m)	1200	1200
Kreuzrahmen / Cross frame	1x	4500	4500
Auslegerteil / Jib part	1x③ (10 m)	710	710
Auslegerteil / Jib part	1x④ (5 m)	370	370
Auslegerteil / Jib part	1x⑤ (5 m)	340	340
Betonfundamentblöcke / Concrete corner blocs	4x	2500	10000
			18620
Turmelement / Towerelement	2xTL 12 (12 m)	2400	4800
Auslegerteil / Jib part	1x① (10 m)	1070	1070
Auslegerteil / Jib part	1x② (10 m)	855	855
Laufkatze / Trolley	1x	390	390
Podeste, Geländer, Abspannungen / Platforms, handrails, bracings		4200	4200
Kiste mit Kleinteilen/Unterflasche / Crate with small parts/hook block		985	985
			12300
Gegenausleger / Counter jib	1x	830	830
Hubwindenplattform / Platform with hoist unit	1x	2310	2310
Gegengewichtssteine / Counterweight stones	5x	1450	7250
Turmspitze komplett / Tower top complete	1x	4000	4000
Führerkabine / Drivers cabin	1x	455	455
			14845

Figure 57: Weight and dimensions of a "packed" and truck-loaded system tower crane

8.1.5. Tower Crane Operation -- Summary

A engineer who has watched a tower crane in action is normally impressed by its performance. Tower cranes can move all but the heaviest loads at high speeds and with precision and safety. Of all the crane designs currently available in the world, a tower crane with a horizontal jib requires the smallest investment of power to achieve the fastest and most efficient output of work. Given the portability of tower cranes, their work potential in shipyards is outstanding.

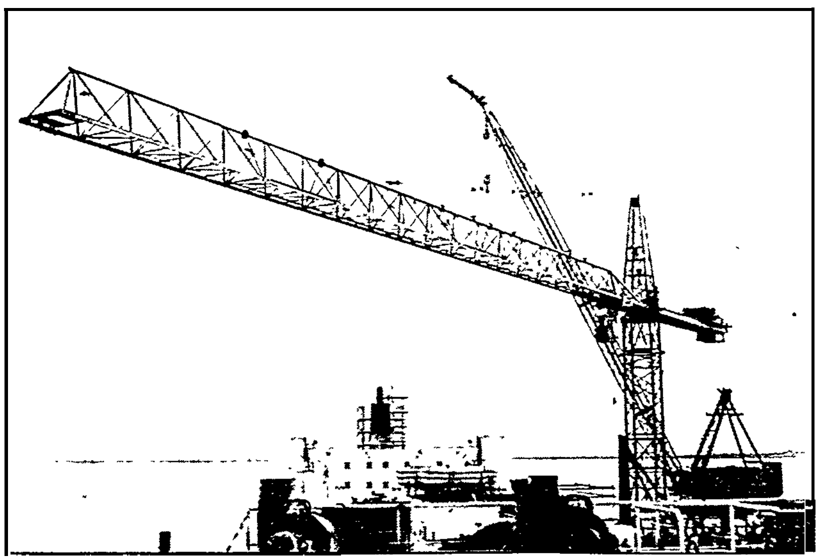


Figure 58: Tower crane type WK 184 SL (from the Wolffkran range) on the deck of a refitting vessel in a U.S. shipyard

8.2. The Tower Crane and the Environment

Many machines are at their most "efficient" when they ignore all environmental considerations, i.e., when they are noisy, dirty, cumbersome, and unsafe. But today the tide is running against such machines: few voices are heard arguing for motorbikes without mufflers or for sprawling industrial development in scenic, waterside areas. In most senses, the tower crane belongs to the ecology-conscious future. As a construction tool , it has traditionally operated in city centerst near schools, hospitals and in residential areas. When used in dockyards, it brings with it the good habits it learned in such areas of high environmental awareness: quiet, safe operation in tight corners.

8.2.1. Noise Level

In direct response to the noise emission standards prevalent in city centers, tower cranes are quiet. Noise level does not normally exceed 80 dbA, a figure that some manufacturers guarantee in writing. This low figure is achieved by restricting the speed of electric motors to 1500 rpm, and by the use of liberally designed gearboxes with helical gears. In the case of hydraulic systems, operational pressure is held below 125 bar, and low-speed or medium-speed drives are exclusively used. For diesel motors special insulation has been developed. Intelligent placing of the prime mover is another factor in noise dissipation. Figure 59 shows this shrewd kind of engineering in practice.

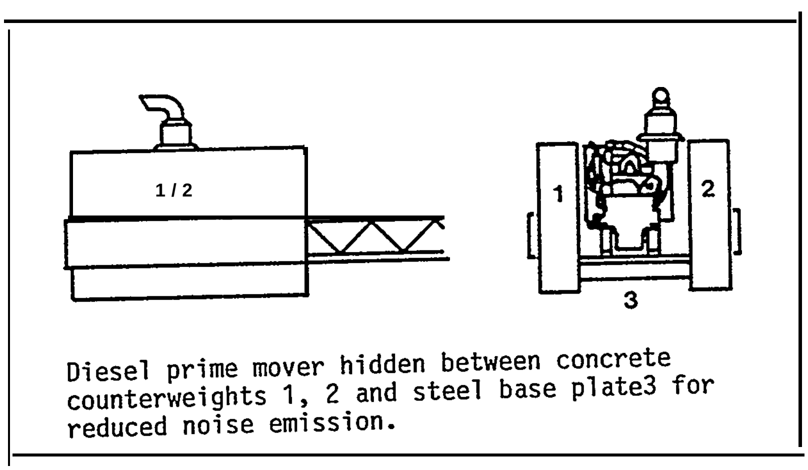


Figure 59: Careful placing of prime mover as noise-control tactic

8.2.2. Space Requirements

The small "footprint" of a tower crane is one sign of its good ancestry. Early shipyards, especially in the U.S., sprawled unmindfully across many acres of waterside property. Today the pressure on space is altogether different. Room for expansion is hard to come by: maybe some rare waterbird lives in the marsh next door; access to the water is needed for recreational purposes; or zoning regulations tie up promising developments. Meanwhile accountants are looking closely at the productivity per square yard of valuable (and perhaps saleable) land. A dockyard today must be planned with space restraints clearly in mind. In terms of "work output per square foot of land occupied," tower crane performance can hardly be bettered. Again, the use of tower cranes in city-center building sites first imposed the design constraints that led to this space advantage.

In fact a range of foundations is available to suit the bearing-strength of the infrastructure and the actual space available. The simplest kind of foundation uses no more than the basic 6-foot square of the tower sections themselves. (See Figure 60, right.) Alternatively, the lowermost section of the tower can be set on four small footplates of 2 foot square each. These footplates can be moved out from the centerline of the crane by means of a crossframe. (See Figure 60, left.) Such "outriggers" can be set 30 feet or more from the centerline. If space demands it, the crossframe can even be constructed asymmetrically. A traveling tower crane has the same size footprint as a big slew crane, but, since the tower crane is mounted on a portal, the space beneath it is available for traffic or storage. The principle is simple: installing a tower

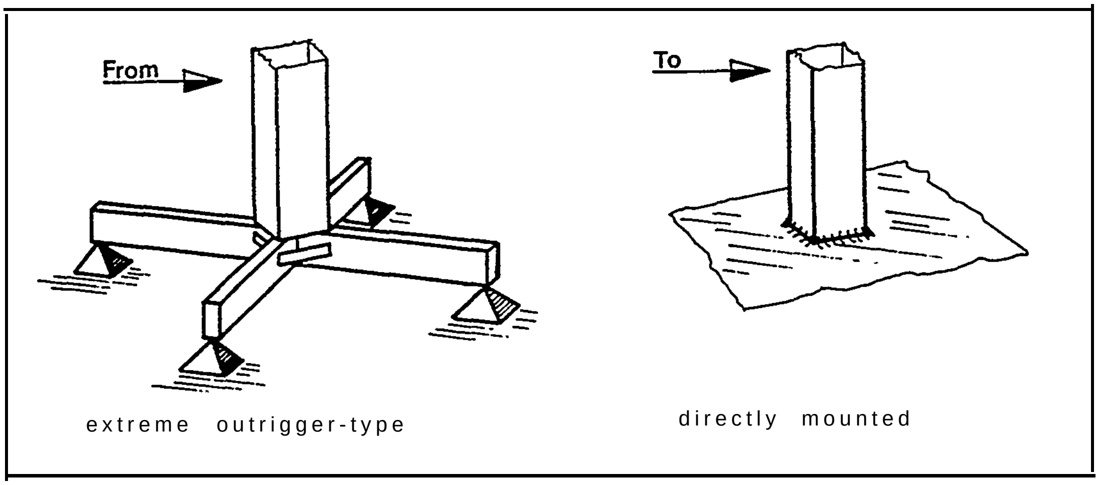


Figure 60: Space-saving foundations for tower cranes

crane makes few demands on space -- usually the foundation can be constructed to fit into the space available. Horizontal-jib tower cranes differ somewhat from luffing-jib tower cranes in their compactness. Particular situations may create a preference for one design.

Horizontal-jib tower cranes need a fair amount free air for the jib to turn without obstruction. Further, top-slewing cranes have a relatively long “tail,” a factor that can be critical when working near other tall structures. Ideally a crane should be free to turn 360° in the wind (to “windvane”). If this is impossible because of nearby structures, the slewcircle can be restricted, or greater stability can be built in. lMore cente1r-ballast, lower tower height, or a stronger tower would all achieve this effect.

Luffing-jib tower cranes do not need as much “free air” as horizontal jibs, but they still need the freedom to “windvane.” Luffing jibs have a weak-spot in gale-force conditions: if the wind directly attacks the “soft underbelly” of the jib~ it can cause stability problems. In areas where gales are expected, extra stability should be built in; also the jib can be placed in its lowermost position or even lowered to the ground.

8.2.3. Safety

Some of the safety features that apply to handling tower cranes have already been mentioned. The safety of the structure itself is also worth emphasizing. All industrialized countries have standards to be met by cranes of all types. In Europe, tower cranes have their own standards, of which the German DIN 15018 is representative.

DIN 15018 is based on the sigma-zul computation, a method for calculating allowable stress; it is also used in some branches of engineering in the U.S. Two loadcases are specified: mainloads (i.e. operating loads) and additional loads, i.e. , windloads. The tables below show the required safety margins.

LOADCASE 1: Mainloads

Mainloads comprise all combinations of deadloads, and hoistloads, including additional dynamic loads from lifting, the inertial forces of the drives, as well as horizontal loads from traversing/luffing, traveling, and slewing.

Safety margins required

Yieldpoint of steels used	1.50
Fatigue of materials and components	1.33
Instability (buckling and bending)	1.71
Instability of crane (overturning)	1.60
Traverse and hoist ropes	4.00

LOADCASE 2: Mainloads plus Additional Loads

Additional loads are, essentially, wind loads

Safety margins required

Yieldpoint of steels used	1.33
Fatigue of materials and components	*
Instability (buckling and bending)	1.50
Instability of crane (overturning) with crane operational; max. allowable wind t	1.50
Instability of crane (overturning) with crane non-operational but free to “windvane”; max. allowable wind	1.20

* Calculated onlv for mainloads

t Maximum operational wind is usually taken as Beaufort 8, or 45 mph (40 knots). Maximum non-operational wind may be set as high as necessary, but is normally taken at Beaufort 14, or 100 mph (90 knots).

Obviously the highest stresses are likely to occur in very bad weather when the crane is shut down. Cranes may also undergo abnormal stress during erectionr especially if tilting of the tower occurs. For the necessary computations, see the manufacturer's manual.

All gear bearings are of the antifriction type and are calculated for a life of 5000 hours at full load. The slew-bearing is (usually) of the centerless ball-race tYpe and has a life of 3200 hours. Although no safety margins have been formulated for axles, gear-wheels and drives? a margin of 1.5 is standard.

Automatic cut-out switches cover all operations. Officially, all hoist-motions must be subject to an automatic limit switch; manufacturers almost invariably fit limit switches for lowering-motions as well. A loadmoment cut-out comes into play at 110% of normal load. Movements of the traversing trolley have inner and outer cut-outs. All control-levers are of the automatic zero-return type, while all portable consoles feature a "dead-man's handle" of some sort. Finally, an emergency shut-down button and a "free windvane" indicator are standard equipment on all tower cranes.

A newly delivered tower crane is as safe a piece of machinery as human wit can make it. If it is correctly maintained and correctly operated, it offers many years of safe and troublefree operation. .

8.3. Cost Factors

Tower cranes, it should by now be clear, are effective in shipyards. The next question must therefore be: Are they cost-effective? It is obviously naive to confuse cost with price -- cut-price bargains have no place in plans to buy capital equipment that could still be in service twenty or even thirty years from now. Such intangibles as the solidity of a crane company, its willingness to support its machines with spare parts over decades, the quality of its consulting staff in the field -- such unquantifiables are all a part of the cost, though they are invisible in the price.

There are tangible considerations too: running costs (including training), maintenance costs, reliability. Each of these must be scrutinized before the long-term cost of a crane becomes apparent.

8.3.1. Initial Cost

Unlike most other cranes, tower cranes are series-system cranes. This allows the purchaser to read the prices off a price-list rather than to negotiate a one-off contract with awkward cost loopholes. More important, the initial investment need cover only short-term plans; no cash has to be tied up to allow for possible, but unlikely, future developments. With system cranes, the tower can be raised or the jib lengthened virtually overnight as need arises. Important too is that system cranes lend themselves to temporary, rental acquisition. A jib section, a carriage, a climber, a tower -- anything can & hired from a local distributor. This represents a huge potential for cutting costs, especially in yards that take on a wide variety of construction, fitting out, refitting, or repair work.

To compare initial cost, the weight of the crane and the “price per ton” must be assessed. The table below is based on recent price-lists and quotations originating from European manufacturers. The current low value of the dollar (mid 1986) is taken into account. All prices are for cranes delivered to site in the U.S.

Type	Deadweight	Cost per ton	Cost/Weight Factor
Goliath (200 ton) (Aux. crab 20 t)	800-1200 t	$4000 - $5300	1.30
Big Slew Crane (Whip hoist 20 t Main hoist 200 t)	375-450 t	$4000 - $5000	1.25
Tower Crane (20 t, top-slewing, luffing)	150-200 t	$3500 - $4200	1.07
Tower Crane (20 t, top-slewing, horizontal jib)	120-180 t	$3200 - $4000	1

Figure 61: Installation cost comparison

The table clearly shows the cost/weight advantage enjoyed by the top-slewing, tower crane with a horizontal jib -- it simply does more work for the weight of steel invested in it.

Sometimes the argument is heard that the big, expensive cranes have a “whip hoist” built in that can cope with the lighter loads at “no extra cost.” In terms of pure installation cost this appears to be true -- until the Cost/Light Load Factor is calculated, i.e., the figure for investment per ton lifted. At that point the absurdity of using a goliath to raise a 20-ton load becomes all too obvious.

Type	Average Initial cost	Cost Per Ton Light-Lifted	Cost/Light Lift Factor
Goliath (200 ton) (Aux. crab 20 t)	$4,650,000	232, 500	8.60
Big Slew Crane (Whip hoist 20 t Main hoist 200 t)	$1,856,250	92, 812	3.44
Tower Crane (20 t, top-slewing, luffing)	$673,750	33, 687	1.24
Tower Crane (20 t, top-slewing, horizontal jib)	$540,000	27 000	1.00

Figure 62: Cost/Light Lift comparison

The very high factors for the goliath and big slewing crane reflect the well-known cost of using the wrong crane for the job. Moving light loads must be the task of light cranes.

Pricing a tower crane, in the first instance, entails making selections from a system. System elements for a top-slewing, horizontal-jib tower crane might appear as in Figure 63 below.

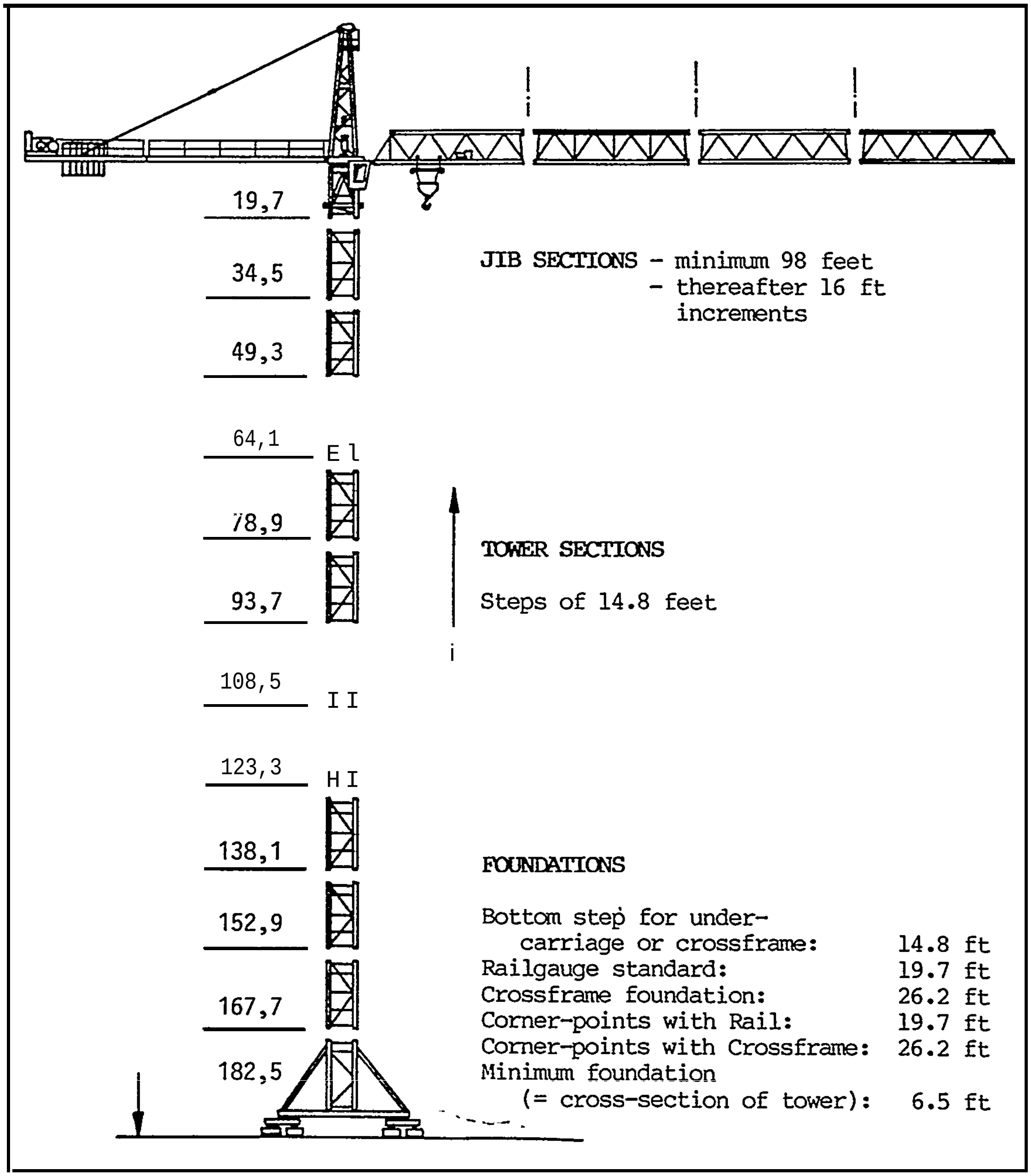


Figure 63: System parts for main structure of a tower crane

8.3.2. Training Costs

Training costs are a halfway house between installation and running costs. Exact figures would probably be meaningless, but certain general guidelines can be suggested.

First, tower-crane drivers require some degree of selection. They must be free of nausea and have no objections to climbing; general good health, good vision and good hearing are important. Some technical and electrical background is obviously desirable. All cranes are potentially lethal instruments; they should never be put into the hands of irresponsible or unstable people.

Recruiting trained drivers for tower cranes is comparatively easy, since there is a large pool of trained people working on construction sites. Trained drivers for goliath or gantry cranes, on the other hand, are much scarcer.

Inexperience on the part of the driver should not endanger life or property in the shipyard. Various built-in safeguards ease the training period considerably. These include:

- Automatic zero-return joysticks
- Automatic overload and loadmoment cut-outs
- Automatic inner and outer traversing cut-outs
- Automatic upper and lower hook approach cut-outs
- Automatic stepped slow-down approach systems

However, it must be stressed that cut-outs are safety devices, not control devices. No skilled driver “hits the buffers” every time. Training is the only way to insure proper operation of the crane.

In a survey of shipyards conducted by the authors, most training programs seem to follow roughly the same lines. In some countries (for example, W. Germany and Canada) training of crane drivers is being made a matter of regulation rather than of individual preference. Interestingly, the “official” programs and the programs in the best yards do not differ in essentials at all. Training falls into three areas: <1> a theoretical grounding in the operation of the crane, its electrical systems, safety systems, and the general principles of load moving; <2> hands-on driving instruction conducted by an experienced “godfather”; and <3> maintenance, again along with a suitable instructor.

The overall cost of training, accordingly, includes: at least one month of training time; slightly lower productivity of the crane during the training period; some wastage as unsuitable candidates are weeded out.

8.3.3. Running Costs

Most tower cranes use electric power. The table below presents the power consumption of one crane for each of the types given in the earlier typology. The Type 2 crane has a stepless hydraulic system, while the others all use straightforward electrical drives. The figure for the Connected Load cannot be derived simply by adding the nominal capacities of various drive motors, since allowance must be made for power loss within the motors themselves (additional 25% capacity needed), and for the fact that slewing, traveling and luffing/traversing do not take Dlace simultaneously (40% reduction in Dower needs). The figures are therefore factored as follows:

Hoist motor	100%
Slewing, traveling, luffing/traversing	60%
TOTAL DRIVE CAPACITY	125%

Auxiliary power figures include a 20% reserve allowance.

	Crane 1	crane2	crane3	crane4
Type	Horizontal jit top slewing	Luffing jib top slewing	Horizontal jib low slewing	Luffing jib low slewing
Make	DLFF WK325SI	~LFF WK320B	KOENIG K65	PEINER T 125
Luffing jib		70.0		37.0
Traverse drive	7.0		3.0	
Slew drive	14.6	30.0	3.5	7.0
Travel	18.4	16.0	6.0	28.0
NON-HOIST CAPACITY TOTAL	40.0	116.0	12.5	72.0
Factor of 60%	24.0	69.6	7.5	43.2
Hoist (load)	76.0	90.0	18.0	50.0
?XYTAL DRIVES	100.0	159.6	25.5	93.2
Factor of 125%	125.0	199.5	31.9	116.5
Heat, light, auxiliary	12.0	12.0	3.0	12.0
Total kw	137.0	211.5	34.9	128.5
Total in KVA (lkw = 0.8KVA)	171.0	264.0	44.0	161.0

Figure 64: Power requirements for tower cranes Type 1 - Type 4

As a rule-of-thumb, the ratio between the total kw requirements and the kilowattage of the main hoist offers a useful running-cost comparison.

	Crane 1	Crane 2	Crane 3	Crane 4
Hoist/Power Ratio	1 : 1.8	1 : 2.4	1 : 1.9	1 : 2.6

Figure 65: Hoist/Power ratios for tower cranes Type 1 - Type 4

The superior ratio achieved by the horizontal-jib cranes (Cranes 1 and 3) reflects, once more, the weight and relative cumbersomeness of luffing-jib cranes in general. The slight edge achieved by the top-slewing cranes (cranes 1 and 2) over the low-slewing versions reflects the cost of slewing the entire tower instead of just the jib. Given these ratios, it is small wonder that 80% of tower cranes worldwide are of Type 1 -- horizontal jib, top-slewing cranes.

A tip on power-saving: it is possible to apply too much power to the drive motors during their acceleration and deceleration phases. A smooth and controlled increase and decrease of power prevents waste.

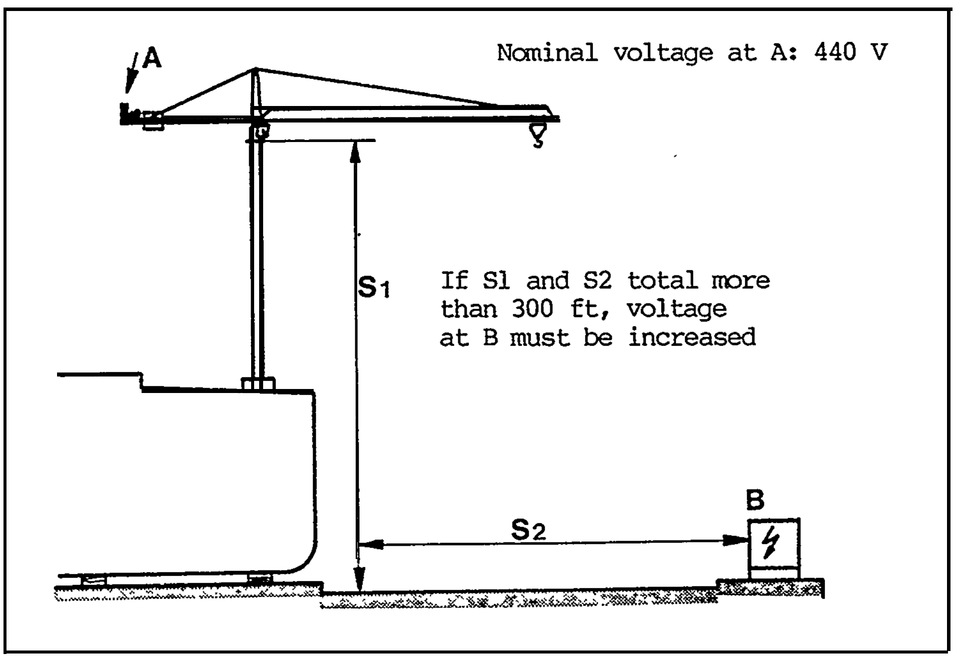


Figure 66: Possible requirement for increased voltage

A final thought on power consumption in tower cranes, especially very high ones. The voltage required to run the drive motors is nominally 440 V. This must be kept within a 5% range. (See Figure 66.) If the distance between the power source <B> and the drive <A> is greater than 300 feet, then the resistance of the mains-cable can cause a drop of more than 5% in voltage. Similarly, ambient temperatures in excess of 110° F can cause a voltage drop. In either case, a heavier gauge mains-cable must be fitted.

8.3.4. Maintenance Costs

There is no significant difference between maintenance costs on a tower crane and maintenance costs on any other type of crane. A alance at a standardized maintenance schedule makes it clear th;t this is so:

Period	Work	Time	Time per month
Daily	Check brakes and limit switches	10 min	4 hrs
Weekly	Check oillevels in gearboxes Check rope condition (esp. grease) Check brake linings (visually or with gauge) Examine all major structural ‘ elements visually	1 hr	4 hrs
Monthly	Check electrical equipment Examine limit switches Examine resistor banks Examine cable connections Examine rail track and foundations	1 hr	1 hr
		TOTAL PER MONTH:	9 hrs

Figure 67: Maintenance times for tower cranes

“Daily” maintenance assumes a single shift of 8 hours. Daily maintenance should be carried out personally by the driver at the start of each shift. Weekly maintenance is based on a 6-day working week; it is best performed as the final task before the weekend shutdown, or, as a time-saver? during stand-by or off-duty periods. Either the driver or the maintenance crew can perform the checks. Monthly maintenance should be carried out by a trained electrician and the driver working together.

In a survey of shipyards, the authors asked for crane-by-crane figures on maintenance times and the cost of replacement parts. Not one of the yards surveyed kept such detailed figures. A consensus agreed, however? that maintenance took up between 3% and 5% of available working time. As to cost, it was generally agreed that maintenance required an outlay of about 2% per annum of the initial purchase price. Cost of spare parts during the first two years of operation was negligible. Between 2 and 8 years, the cost was about 2% of initial purchase price, after which it might climb to 3%. It can thus be seen that maintenance costs do not differ significantly between tower cranes and other types of crane.

A crane is safe only as long as it is properly installed and properly maintained. A word of warning. Preventive maintenance on a tower crane must place special emphasis on the integrity of each individual strut and diagonal in the main structure. It is apparent from an examination of shipyards worldwide that a bent railing? a deformed gangway or a twisted pole are often dismissed as trivialities. Do not make the mistake of extending this careless attitude to the structural elements of a tower crane. Structural damage should be a matter of immediate concern: only speedy repair or replacement can guarantee continued safe operation.

There is one further maintenance area where tower cranes require special treatment. Tower cranes can be dismantled and reassembled. The devices used to lock the sections in place are obviously subject to wear and tear. First a word on the various locking systems. There are two main families of locking devices: <1> ht bolts and <2> what are variously called push-pins, slug-bolts, or pushbolts . Figure 68 illustrates three common connections using ht bolts.

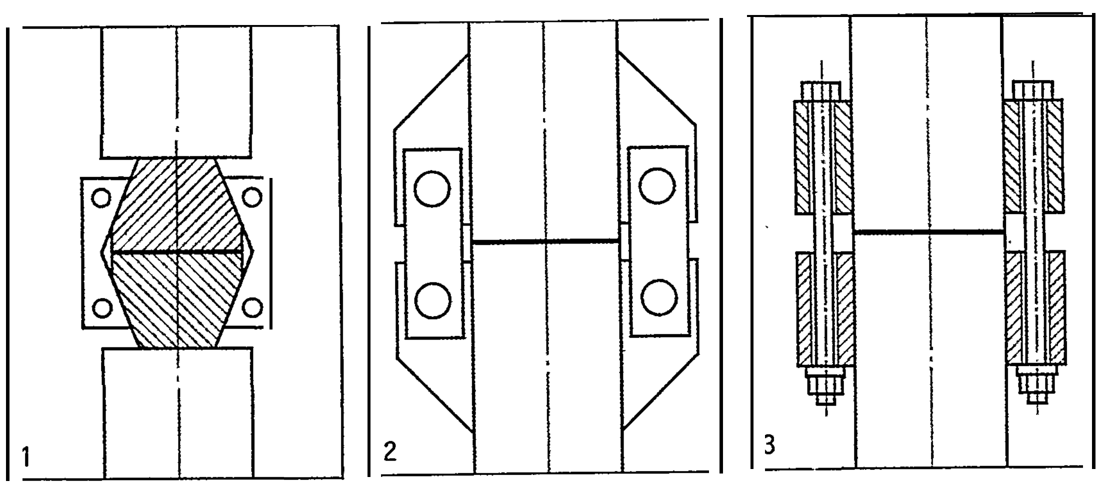


Figure 68: Typical tower connections using ht bolts

The cutaway diagram (Figure 69 overleaf) shows the more recent trend: the use of slug-bolts. This system is both simple to use and extremely safe: there is no danger of overtorquing, and wear and tear on the slug-bolts are far less than on the comparable threaded ht-bolts.

The choice between the two systems can have a measurable effect on maintenance costs. This effect increases with the frequency of disassembly and reassembly of the crane. With ht bolts, great care must be taken to distinguish between oil-coated ht

bolts and the molybdenum-coated version. Torauina requirements differ drastically between the two types. (S&e Fugure 70.)

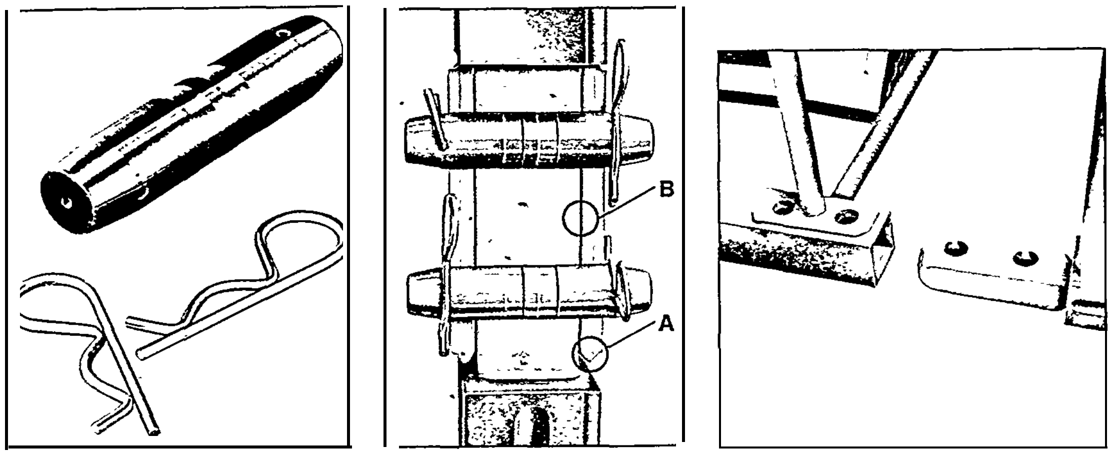


Figure 69: Slug-bolt tower connection as used by MAN-Wolffkran

In practice, many bolts are overtorqued. This means time wasted during reassembly of the tower, and excessive wear and tear on the bolts themselves *as* well as extreme danger to the *crane*.

	1	2	3	
	Bolt diameter (mm)	Wanted prestress.ing force inside bolt	Prestressingbolt Torque moment needed MoS2 Lubricated	
		ton f **	Nm	ft. lb
1	M 12	5	100	70
2	M 16	10	250	180
3	M 20	16	450	325
4	M 22	19	650	470
5	M24	22	800	580
6	M27	29	1250	905
7	M 30	35	1650	1180

Figure 70: Torquing table for ht bolts

Some yards that move an ht-bolt crane 3 or 4 times a year, report replacement-part costs rising to 5% of initial cost. Further, the torquing on ht bolts must be checked after a move, representing an additional cost. With the slug-bolt system, this problem is resolved. Slug-bolts require no torquing, they are quick to install and to remover and, beyond greasing on each reuse, they are maintenance-free. Slug-bolts, as already seen in Figure 691 are used with a stud\sleeve connection system. This system allows a 2.0 safety margin: experimentally cranes have been found to be safe with 50% of the slug-bolts missing.

Overall, a tower-crane using slug-bolts will require about the same maintenance outlay as most other cranes, though the figure for a tower crane using ht bolts could be appreciably higher. While some cranes, for example the level-luffing “gooseneck” cranes, contain many moving parts and arer therefore? relatively costly to maintain, the authors know of no crane that is requires appreciably less maintenance than a modern tower crane.

8.3.5. Reliability

Finally, the great hidden cost factor -- reliability. Comparative reliability figures are simply not available and in any case would be meaningless: they would give more information about the maintenance standards in particular shipyards than about the reliability of crane types. There are, however, three significant pointers.

First, as already emphasized, tower cranes were first conceived as construction cranes, and the requirements of the construction industry are, if anything, more exacting than those of shipbuilders. Let us say a crane breaks down during the pouring of a concrete floor thirty stories up. If the half-poured concrete sets, the financial consequences could be disastrous. Tower cranes are not sensitive, temperamental quarter-horses but reliable, sensible work-horses.

The second pointer is the simplicity of design of a tower crane. This is the simplicity of sophistication, not that of underdevelopment. A few years back, tower crane design risked becoming overloaded with fancy extras. A design revolution, sparked by Wolffkran, reversed the trend, putting simplicity and reliability ahead of such refinements as elevators to take the operator up to his cab or an on-board toilet. The new trend was not hard to sell to customers: it cut initial costs, reduced maintenance, and, as simplicity became the essence of good design, progressively increased reliability. Simple design is one of the best guarantees of reliability.

Finally, of course things do go wrong. When this happens, down-time must be a short as possible. Simple design means that many repairs are within the scope of the maintenance crew in the yard itself. Further, because tower cranes are series cranes, spare parts are usually available “off the shelf.” Waiting for a replacement part for a custom-built crane can take months, while replacement parts for tower cranes are often available “round the corner.” When the parts are delivered, they can usually be installed in a few hours. Due to clever engineering, this is generally true even of major parts such as slew-bearings. Partly, of course, these benefits depend on the shipyard choosing in the first place a manufacturer who is well represented by distributors and sub-distributors in the United States.

In conclusion, no one type of crane has a monopoly on reliability. The tower crane, however, due to its ruggedness, to its deliberately simple engineering, and to the ready availability of replacement parts, can take its place among the most reliable machines ever built.

8.4. User Survey

Tower cranes, both series models and custom-built, are already in service in the United States. The experience of six major shipyards has been solicited and is offered here in tabular form.

1. AVONDALE SHIPYARD, New Orleans, Louisiana
2. NASSCO, San Diego, California
3. BLUDWORTH-BOND, Houston, Texas
4. NEWPARK SHIPBUILDING, Houston, Texas
5. M.M.I., Houston, Texas
6. NORSHIPCO, Norfolk, Virginia

We would like to thank the yards concerned for their valuable help in preparing this survey.

SHIPYARD 1: AVONDALE SHIPYARD, New Orleans, Lousiana

TOWER CRANES IN USE: 10 units

MAKES AND TYPES: Mostly Peiner-Pecco, 3 Linden, 1 self-erecting fast tower

NORMAL APPLICATIONS: platens, Pipe shop, Sandblasting and painting area, Dry-dock servicing

SPECIAL USES: 1 crane mounted on floating pontoon; frequent temporary mounting on deck of ship

AVERAGE DAILY USE: Some in constant use; some used as needed. Average: 4 hours per shift

MAINTENANCE : Minimal as to cost and time; mostly minor electrical problems

DOWNTIME: Minimal

ADVANTAGES:
- Cheaper installation.
- Release heavy cranes for performing heavy lifts.
- Easy to move.
- Fast cycle time.
- Reduced cost per lift.

DISADVANTAGES :
- Limited capacity.
- Sometimes obstruct larger cranes.

COMMENTS: Tower cranes have greater output for the investment. Avondale will buy more tower cranes when needed.

SHIPYARD 2: NASSCO, San Diego, California

TOWER CRANES IN USE: 2 units

MAKES AND TYPES: 1 Wolff WK 184 SL
1 King K-65

NORMAL APPLICATIONS: The Wolff is on the deck of a ship for loading and fitting-out
The King is in the steel-yard

SPECIAL USES: The siting of the Wolff is unusual for this yard

AVERAGE DAILY USE: Full 8-hour shift; 50-60 lifts per shift

MAINTENANCE : Minimal

DOWNTIME: Minimal

ADVANTAGES:
- More light loads moved more quickly than with other cranes.
- Large gantries are released for shifting heaviest loads.
- Easy moving from one area to another without dismantling.
- Cheaper operation.
- Smaller crane crews.
- Cost per lift greatly reduced.

DISADVANTAGES :
- None reported

COMMENTS: NASSCO will buy more tower cranes if needed.

SHIPYARD 3:	BLUDWORTH-BOND, Houston, Texas
TOWER CRANES IN USE:	2 units
MAKES AND TYPES:	Liebherr 250 C Liebherr 190 C
NORMAL APPLICATIONS:	Repairwork and servicing in dry dock; store room and plate area
SPECIAL USES:	None reported
AVERAGE DAILY USE:	3 hours per shift (6 hours per day)
MAINTENANCE:	Minimal cost or time
DOWNTIME:	Minimal
ADVANTAGES:	• Speed • Horizontal, non-luffing jib
DISADVANTAGES :	Free windvaning in excluded by space in the yard; therefore the cranes must be shut down completely in high winds.
COMMENTS:	Tower cranes do a better job for less money. Bludworth-Bond will buy more if needed.

SHIPYARD 4: NEWPARK SHIPBUILDING, Houston, Texas

TOWER CRANES IN USE: 2 units

MAKES AND TYPES: Liebherr 300 C
Richier

NORMAL APPLICATIONS: Service drydock for repair work; Store room

SPECIAL USES: The Liebherr travels 450 feet on bogies

AVERAGE DAILY USE: 4 hours per shift

MAINTENANCE: The Liebherr is more expensive to maintain than a crawler crane

DOWNTIME: Tower cranes break down more often than a crawler, but don't stay down for as long

ADVANTAGES: Reach a very large service area

DISADVANTAGES : Limited capacity

COMMENTS: If the capacity of a tower crane meets the application, it does a better job for the money

SHIPYARD 5: M.M. I. , Houston, Texas

TOWER CRANES IN USE: 1 unit

MAKES AND TYPES: Linden Type 8650

NORMAL APPLICATIONS: Topside repair work on ship

SPECIAL USES: None reported

AVERAGE DAILY USE: 3 to 4 hours per shift

MAINTENANCE : Minimal cost or time

DOWNTIME: Minimal

ADVANTAGES:
- Large operational field
- Low cost per lift
- Low cost of operation

DISADVANTAGES : None reported

COMMENTS: Tower cranes do more work for the investment. M.M.I. will buy more tower cranes if needed

SHIPYARD 6: NORFOLK SHIPBUILDING AND DRYDOCK, Norfolk, Virginia

TOWER CRANES IN USE: 6 units

MAKES AND TYPES: 3 Liebherr (including a very large 1800 mt unit)
1 Kr411 1800 mt
1 Linden
1 Pecco-Peiner

NORMAL APPLICATIONS: Outfitting; Drydock; Platens; Pier

SPECIAL USES: The Krbll travels on a portal

AVERAGE DAILY USE: On a yearly basis, the Krbll averages 8000 hours, the Liebherr 6500 hours, the others 2000 - 2500 hours

MAINTENANCE : At first, due to lack of experience, maintenance was costlier. Now it is the same as for other cranes.

DOWNTIME: No significant comment

ADVANTAGES:
- Operator has enhanced field of vision
- Superior reach and radius
- Safe against overload
- More accurate load-placing than luffing-jib cranes

DISADVANTAGES :
- Limited capacity
- Higher sensitivity to wind conditions when operating

COMMENTS: Although tower cranes are not necessarily the best for all applications, for some applications they have great advantages. Norfolk will buy more tower cranes if needed.

User Survey: Summary

Half the yards surveyed said that the “limited capacity” of the tower crane was a disadvantage. The use of gantry cranes and goliaths with their radically different geometry is necessary for very heavy lifts -- a balanced system that could compensate for loads weighing thousands of tons is an engineering impossibility. Properly understood, the “limited capacity” observation is rather flattering to the tower crane: “We wish~” the comment seems to say, “that we could do all the work in our yard with tower cranes.” Be that as it may, a tower crane has an upper size limit; it is a complement to the goliath, not a David-style rival.

Problems with wind are mentioned by two yards. Where free windvaning is not possible, gale force winds will definitely cause some loss of time, though no additional safety hazard.

Potential problems with maintenance costs and downtime, a common concern of U.S. purchasers, were not, in general, encountered by any of the yards surveyed; 4 yards simply labeled maintenance and downtime “Minimal.”

The special advantages of tower cranes clearly outweigh the problems in the minds of American users. Operational advantages include the large service area reached (3 yards)~ speed of operation (3 yards), the release of super-heavy cranes for their specialized work (2 yards), and the portability of tower cranes (2 yards). Accurate load placing and safety from overload were also mentioned as special considerations. The cost/speed advantages of the tower crane were stressed by no fewer than 5 yards.

Overall, the 6 yards questioned unanimously felt that they would purchase tower cranes again if the need for them arose.

8.5. Summary

No large investment should be made without considering all the angles. In the short-term, the tower crane offers a build-now, expand-later economy that makes sense in a rapidly changing industry such as shipbuilding. The series-system nature of the tower crane, with its potential for accessory rentals, makes it unusually interesting to yards that take on many kinds of work. Long-term costs, measured in terms of training, running costs, maintenance and reliability show tower cranes either as the equal of any other type, or as having a definite competitive edge.

9. CONCLUSIONS AND RECOMMENDATION

9.1. Conclusion

While American shipbuilders have been slow to spot the advantages of the tower crane, shipyards in Europe and the Far East have exploited them with increasing sophistication in recent years.

Unlike many shipyard cranes, the European tower cranes are series manufactured, which brings immediate cost benefits as well as ensuring the supply of spare parts for years to come. Series crane design has led manufacturers to develop tower crane systems -- allowing for interchangeability of parts, high portability and extreme flexibility of operation. An extensive rental system allows the user to rebuild an existing crane with rented parts for special, one-off jobs.

Experience with tower cranes has shown that they are no more difficult to operate than other type of crane; indeed the tower crane enjoys certain advantages when it comes to load placing. Speed, i.e., the amount of work per shift that a tower crane produces, puts it ahead of any rivals in the light- and medium-lift classes. This is particularly true of the horizontal-boom version -- a crane that is slowly becoming the workhorse of the world. Because of its common use in city-center building sites, the tower crane is engineered with quiet operation, safety and economy of space in mind -- all factors on which ship-builders must also place a high premium.

The cost-effectiveness of the tower crane appears from a variety of perspectives. First, the tower crane yields nothing to other crane designs when it comes to training and maintenance costs. Then, running costs are definitely advantageous, and, given normal maintenance, the simple design of the crane insures high reliability. The initial cost of the crane is perhaps its most interesting feature. In terms of cost per ton of capacity, the tower crane is without doubt cheaper than other. types of crane. The fact that series parts can be added later, or even rented, keeps initial investment under a very tight lid.

The tower crane is not built for very heavy lifts -- these must be left to the big slew cranes or the goliaths. But the problem in most yards is not a lack of superlift capacity -- it is bottlenecks. When, for example, a goliath is required to do virtually all the lifting work during a refit, the pace of work becomes ragged, skilled workers are left idle sometimes for hours, and late deliveries can result. With a tower crane installed, permanently or temporarily, the goliath is free to do the job it was built to do, while the speed and convenience of the tower crane increase the productivity of the workforce. The

synergistic effect is outstanding. With each crane do~ng the job it does best, the work flows smoothly and deadlines can be kept.

9.2. Recommendation

This report recommends that shipyards where a lack of auxiliary lifting capacity causes bottlenecks should consider installing one or more tower cranes. Shipyards contemplating expansion or re-equipping should also plan to integrate traditional heavy-lift cranes and fast, efficient tower cranes.

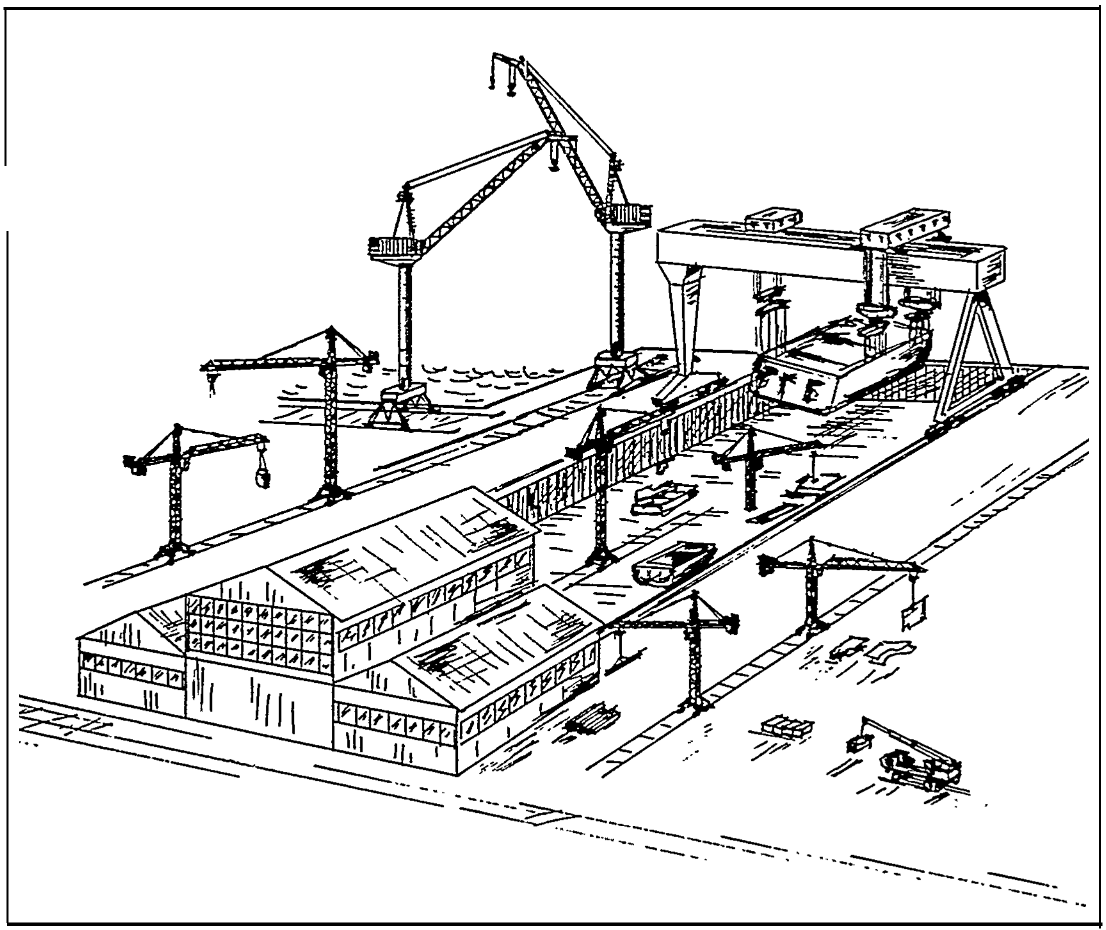


Figure 71: Every crane should do the job it was built to do